(15) Specimen B_4. (16) Specimen B_4. (17) Specimen B_6.

FIG. 162.—Electrolytic Copper Deposit for Protection During Polishing. Etching: 2 Per Cent HNO_3 in Alcohol. $\times$ 280.

carbon dioxide is shown. The microscopic examination of the fused metal shows unmistakable evidence of the presence of some plates, although they differ somewhat from those found in nitrogenized iron and in metal fused in the air by the electric arc. Evidently they are due to a different cause from the majority of those formed in the iron fused in air. For convenience, in the remainder of the discussion the "plates" will be referred to as "nitride plates."

Relation of Microstructure to the Path of Rupture.—The faces of the fracture of several of the tension specimens after testing were heavily plated electrolytically with copper so as to preserve the edges of the specimens during the polishing of the section and examined microscopically to see if the course of the path of rupture had been influenced to an appreciable extent by the microstructural features. In general, the fracture appears to be intercrystalline in type. Along the path of rupture in all of the specimens were smooth-edged hollows, many of which had evidently been occupied by the "metallic globules" referred to above, while others were gas-holes or pores. Portions of the fracture were intracrystalline and presented a jagged outline, but it cannot be stated with certainty whether the needles have influenced the break at such points or not. (16) shows the appearance of some of the fractures and illustrates that, in general, the "nitride plates" do not appear to determine to any appreciable extent the course of the path of rupture.

The behavior of the plates under deformation can best be seen in thin specimens of the metal which were bent through a considerable angle. Results of examination of welds treated in this manner have been described by Miller. Small rectangular plates of the arc-fused metal, approximately $^3/_{32}$ in. thick, were polished and etched for microscopic examination and were then bent in the vise through an angle of 20 deg. (approximate).

In (18) to (21), Fig. 163, inclusive are given micrographs illustrating the characteristic behavior of the material when subjected to bending. For moderate distortion the nitride plates influence the course of the slip-bands in much the same way that grain boundaries do—i.e., the slip-bands terminate usually on meeting one of the plates with a change of direction

so that they form a sharper angle with the plate than do
the portion of the slip-band which is at some distance awa
(18). When the deformation is greater the slip-bands occu
on both sides of the nitride plate, but usually show a sligh
variation in direction on the two sides of the nitride plat
(19); this is often quite pronounced at the point where th
plate is crossed by the slip-band. In a few cases evidenc

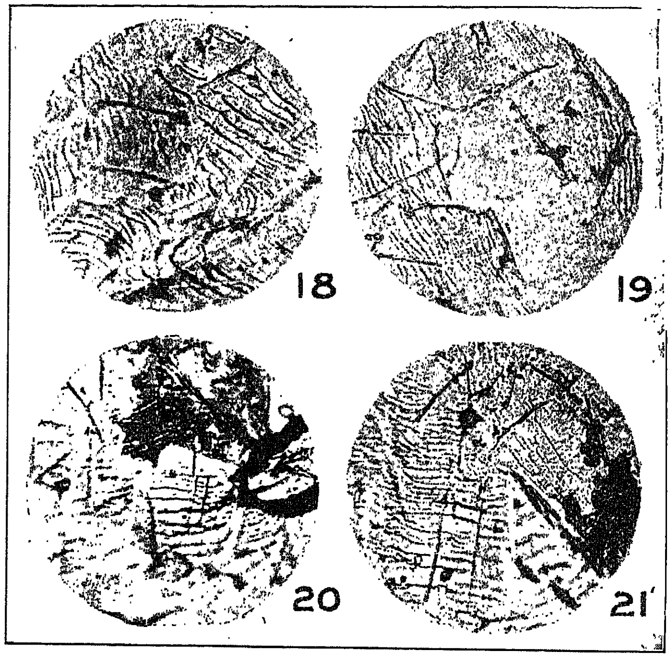


FIG. 163.—(18 to 21) Behavior of "Nitride Plates" During Plastic De-formation of the Iron. Specimen RD_2, Etched with 2 Per Cen Alcoholic, Nitric Acid Before Bending. $\times$ 500.

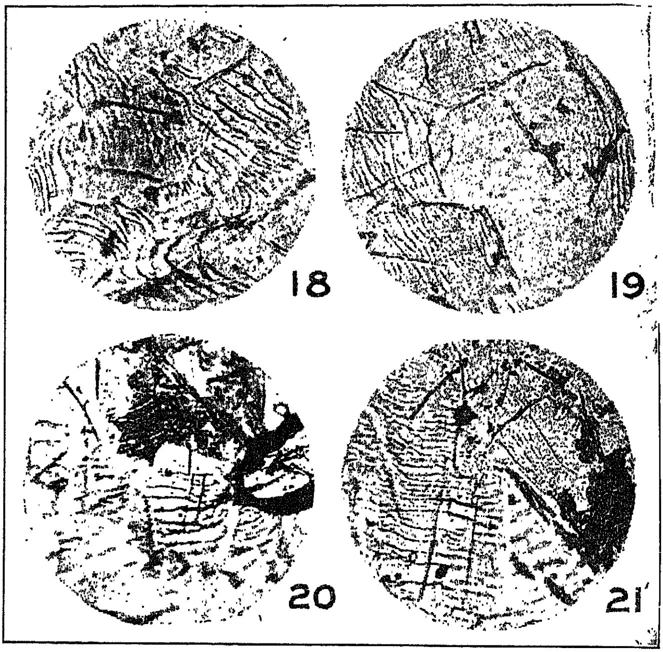
of the "faulting" of the plate as a result of severe distortion
was noted (20). This was a rare appearance, however, becaus
of the nature of the metal, and is not shown in (21). On
account of the inclusions and other features of unsoundnes
of the metal, rupture occurs at such points before the sound
crystals have been sufficiently strained to show the character-
istic behavior of the plates. Other micrographs show the
beginning of a fracture around one of the "metallic globule"

inclusions before the surrounding metal has been very severely strained. For this reason the influence of the plates on the mechanical properties of the crystals cannot be stated with certainty. It would appear, however, that on account of the apparently unavoidable unsoundness of the metal, any possible influence of the nitride plates upon the mechanical properties of the material is quite negligible.

Some of the same specimens used for cold bending were torn partially in two after localizing the tear by means of a saw cut in the edge of the plate. The specimen was then copper plated and prepared for microscopic examination, the surface having been ground away sufficiently to reveal the weld-metal with the tear in it. The nitride plates did not appear to have determined to any extent the path taken in the rupture produced in this manner.

Effect of Heat Treatment Upon Structure.—With the view of possibly gaining further information as to the nature of the plates (assumed to be nitride), which constitute such a characteristic feature of the microstructure, a series of heat treatments were carried out upon several specimens of arc-fused electrodes of both types. Briefly stated, the treatment consisted in quenching the specimens in cold water after heating them for a period of ten or fifteen minutes at a temperature considerable above that of the Ac_3 transformation; 925, 950 and 1,000 deg. C. were the temperatures used. After microscopical examination of the different quenched specimens they were tempered at different temperatures which varied from 600 to 925 deg. C. for periods of ten and twenty minutes. The samples which were used were rather small in size, being only $\frac{1}{8}$ in. thick, in order that the effect of the treatment should be very thorough, were taken from test bars A_2, A_3, AD_{10}, B_2, B_6 and B_9. These represented metal which had been deposited under different conditions of current density, as shown in Table X. No plates were found to be present in any of the specimens after quenching. (22) Fig. 164 shows the appearance of one of the quenched bars, a condition which is typical of all. The structure indicates that the material comprising the plates had dissolved in the matrix of iron and had been retained in this condition upon quenching. The needle-like striations within the individual grains are char-

so that they form a sharper angle with the plate than does the portion of the slip-band which is at some distance away (18). When the deformation is greater the slip-bands occur on both sides of the nitride plate, but usually show a slight variation in direction on the two sides of the nitride plate (19); this is often quite pronounced at the point where the plate is crossed by the slip-band. In a few cases evidence



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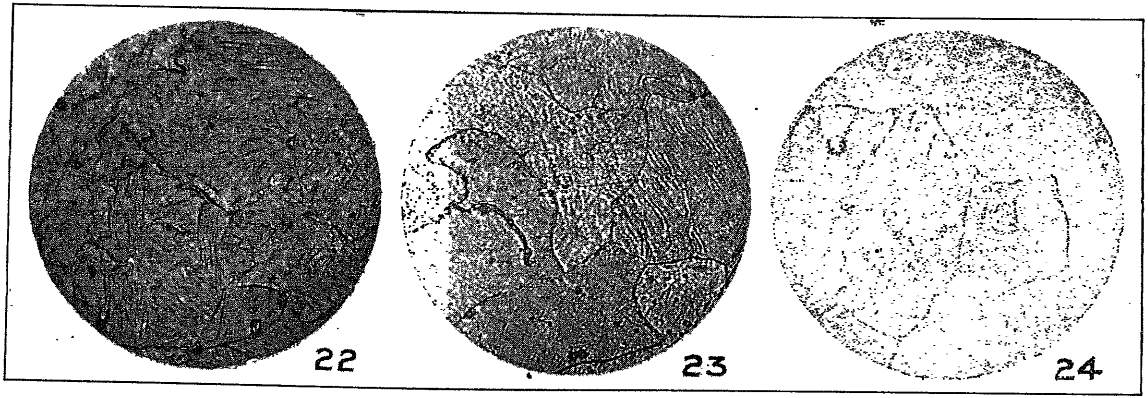


FIG. 164.—(22) Specimen AD_{10} Quenched in Cold Water from 1000 Deg. C., Suppressing Nitride Plates and Developing Martensitic Structure. Etched with 5 Per Cent Alcoholic Picric Acid. $\times$ 500.

FIG. 164.—(23) "A" Electrode Quenched in Cold Water from 1000 Deg. C. Faint Martensitic Markings, Especially Near Surface. Etched with 2 Per Cent HNO_3 in Alcohol. $\times$ 500.

FIG. 164.—(24) Same as (23), but Showing Interior Markings Suggestive of "Plates" of Arc-Fused Metal. Etched with 2 Per Cent HNO_3. $\times$500.

acteristic of the condition resulting from the severe quenching and are to be observed at times in steel of a very low carbon content. (23) shows the appearance of one of the "A" electrodes ($^5/_{32}$ in.) quenched in cold water from 1,000 deg. C. Some of the crystals of the quenched iron also show interior markings somewhat similar in appearance to the nitride plates (24). These are, however, probably of the same nature as the interior tree-like network sometimes seen in ferrite which has been heated to a high temperature. The striations were found to be most pronounced in the specimens of arc-fused metal which were quenched from the highest temperatures, as might be expected. Braune states that nitride of iron in quenched metal is retained in solution in the martensite. The same may be inferred from the statement by Giesen that "in hardened steel, it (nitrogen) occurs in martensite." Ruder has also shown that nitrogenized electrolytic iron (3 hr. at 700 deg. C. in ammonia) after being quenched in water from temperatures 600 to 950 deg. C. shows none of the plates which were present before the specimen was heated.

The sets of specimens (A_2, A_6, AD_{10}, B_2, B_6 and B_9) quenched from above the temperature of the Ac_3 transformation were heated to various temperatures, 600, 700, 800 and 925 deg. C. In all cases the specimens were maintained at the maximum temperature for approximately ten to fifteen minutes and then cooled in the furnace. (25) to (30), Fig. 165, inclusive summarize the resulting effects upon the structure. Heating to 650 deg. C. is not sufficient to allow the plates to redevelop, but in the specimens heated to 700 deg. C. a few small ones were found. The effect is progressively more pronounced with the increased temperature of tempering, and in the material heated to 925 deg. C. they are as large and as numerous as in any of the arc-fused specimens. The heating also develops the islands of pearlite which are not always to be distinguished very clearly in the simple fused metal. The work of Ruder shows that nitrogenized iron which has been quenched and so rendered free from the nitride plates behaves in a similar manner upon heating to temperatures varying from 700 to 950 deg. C.; the plates reappear after a heating for fifteen minutes at 700 deg. C. (or above), followed by a slow cooling. The similarity in behavior of the two is a

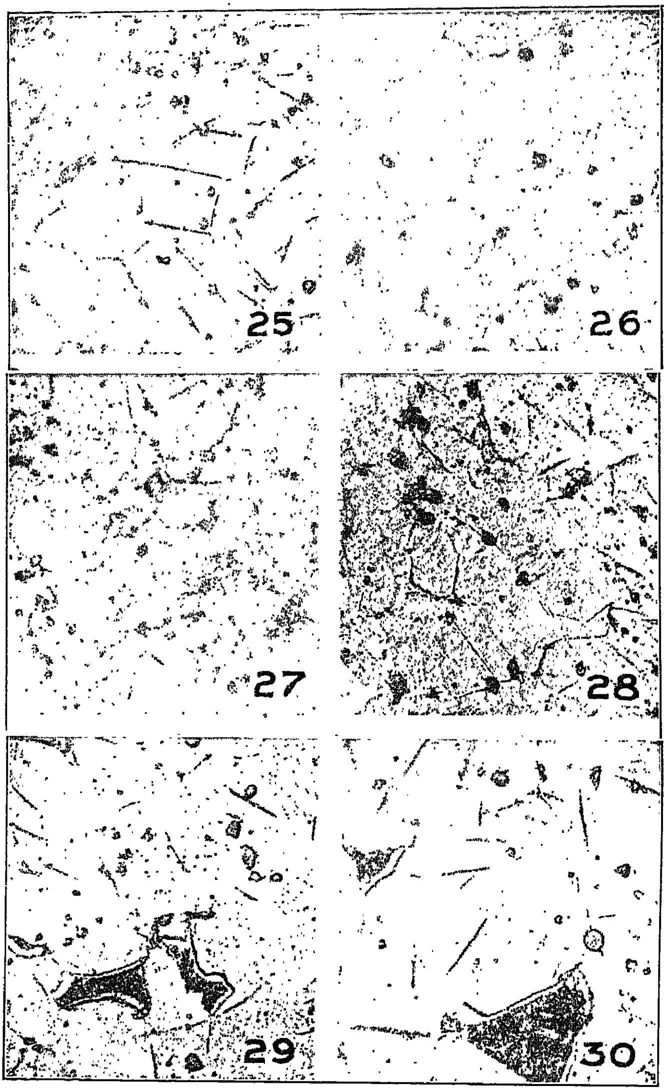


FIG. 165.—(25 to 30) Effect of Heat-Treatment of Arc-Fused Iron.

All etched with 2 per cent alcoholic HNO_3. × 450.

(25) Specimen AD_{10} as deposited.

(26) Same after quenching from above HC_3 and reheating to 650 deg. C. No "plates" have formed.

(27) Specimen AD_{10} after quenching from above HC_3 and reheating to 700 deg. C. "Plates beginning to reform.

(28) Specimen B_9 after quenching from above AC_3 and reheating to 800 deg. C.

(29) Specimen B_2 after quenching from above AC_3 and reheating to 925 deg. C.

(30) Specimen A_2 after quenching from above AC_3 and reheating to 925 deg. C.

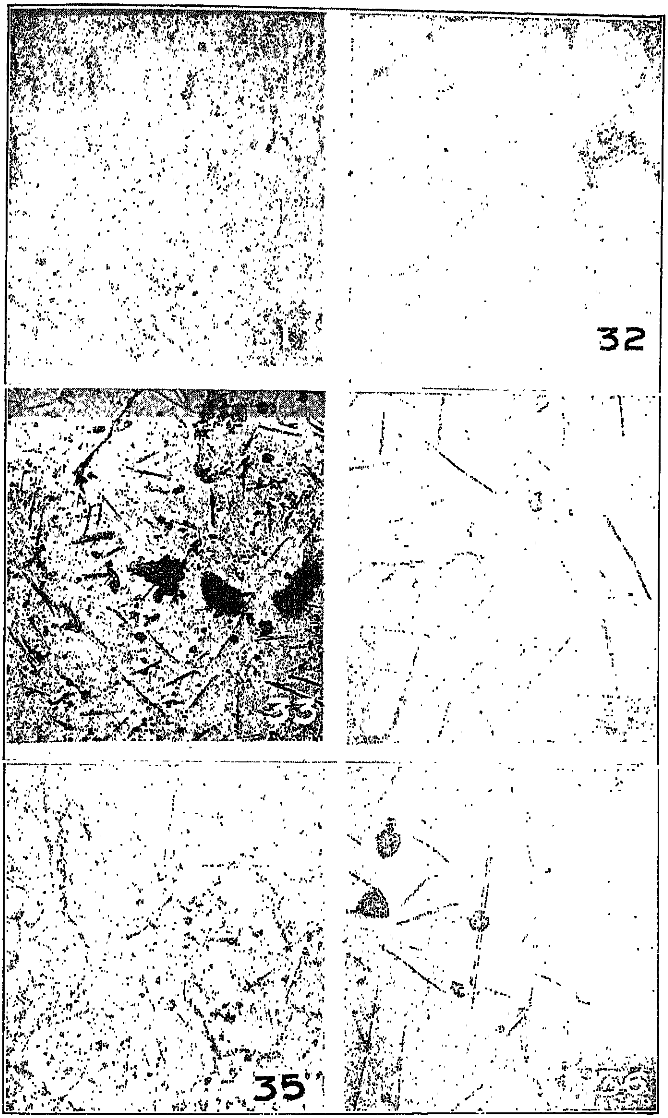


FIG. 166.—(31 to 36) Effect of 6-hr. Heating at 1000 Deg. C. in Vacuo.
All etched with 2 per cent alcoholic HNO_3. × 450.

(31) Initial structure of AD_2.
(32) AD_2 after heating.
(33) Initial structure of B_4.
(34) B_4 after heating.
(35) Initial structure of A_{10}.
(36) A_{10} after heating.

further line of evidence that the arc-fused metal contains more or less nitrogenized iron throughout its mass.

Plates Remain After Long Annealing.—The persistence of the nitride plates was also studied in specimens heated at 1,000 deg. C. *in vacuo* for a period of 6 hr. A set of specimens (one each of test-bars AD_2, A_3, AD_6, A_{10}, B_2, B_4, B_5 and BD_5) was packed in a Usalite crucible, and covered with alundum "sand"; this crucible was surrounded by a protecting alundum tube and the whole heated in an Arsem furnace. A vacuum,

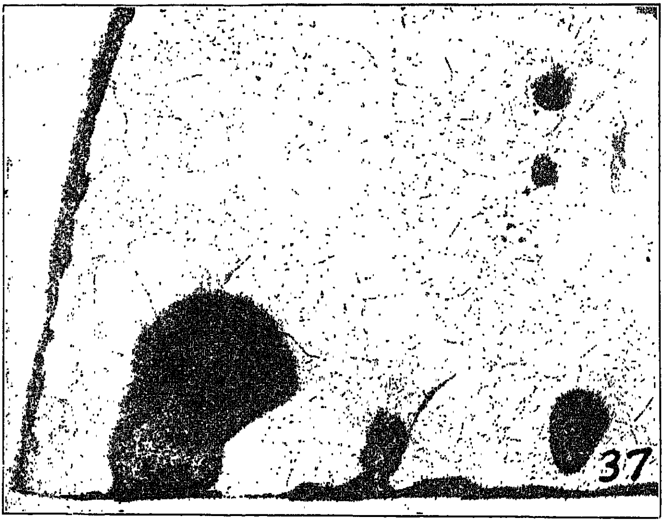


FIG. 167.—(37) Effect of Pronounced Heating Upon the Structure of Arc-Fused Iron.

Specimen AD_{10} was heated for 6 hr. in vacuo at 1000 deg. C. The micrograph represents a section of the specimen at one corner. The oxide and "nitride plates" have been removed in the exposed tip of the thread. Etching, 2 per cent alcoholic solution of nitric acid. × 150.

equivalent to 0.2 mm. mercury, was maintained for the greater part of the 6-hr. heating period; for the remainder of the time the vacuum was equivalent to 0.1 to 0.2 mm. mercury. The specimens were allowed to cool in the furnace. Ruder has stated that 1 hr., heating *in vacuo* at 1,000 deg. C. was sufficient to cause a marked diminution in the number of plates in both arc-weld material and nitrogenized iron and that at 1,200 deg. C. they disappeared entirely.

The results obtained are shown in (31) to (36), Fig. 166,

inclusive. In contradistinction to Ruder's work the plates are more conspicuous and larger than before, the oxide specks are larger and fewer in number. Many of the "plates" appear to have been influenced in their position by an oxide globule. It would appear that the conditions of the experiment are favorable for a migration of the oxide through an appreciable distance and for a coalescing into larger masses. (32), (34) and (36) all show some cementite at the grain boundaries which resulted from the "divorcing" of pearlite. The oxide is eliminated entirely in a surface layer averaging approximately 0.15 mm. in depth. Only in projections (right-angled corners, sections of threads of the tension bar, etc.), was there any removal of the nitride plates by the action of the continued heating *in vacuo*. This is shown in (37), Fig. 167, which illustrates the removal of the oxide inclusions also. No evidence was found that the small amount of carbon present in the arc-fused metal is eliminated, particularly beneath the surface.

(6) Fig. 158 illustrates an interesting exception to the rule that the nitride plates are flat. In the metallic and globular inclusion shown the plates have a very pronounced curve. The general appearance suggests that the "metallic globules" solidified under a condition of "constraint" and that this condition still persists even after the 6-hr. heating at 1,000 deg. C. which the specimen received.

Several of the specimens which were heated *in vacuo* (6 hr. at 1,000 deg. C.) were analyzed for nitrogen. The results are given in Table XVI.

TABLE XVI.—CHANGE IN NITROGEN CONTENT UPON HEATING

Specimen	Wt. of Sample in Gr.	Average Nitrogen Content, per Cent: Before Heating	Average Nitrogen Content, per Cent: After Heating in Vacuo.	Loss per Cent
A_3....................	1.39	0.127	0.062	51
B_4....................	6.0	0.124	0.078	37
BD_5....................	1.62	0.140	0.059	57
B_5....................	1.16	0.121	0.054	55

The fact that the specimens lose nitrogen upon heating (although the amount remaining is still many times the nitrogen-content of the metal before fusion), coupled with the fact that the "nitride plates" are larger and more con-

spicuous after heating than before, suggests very strongly that these plates are not simple nitride of iron. The method used for the determination of nitrogen gives only the "nitride" nitrogen, hence a possible explanation for the change in nitrogen content is that it has been converted into another form than nitride and may not have been eliminated from the specimen.

Thermal Analysis of Arc-Fused Steel.—In order to throw further light on the nature of the plates (nitride) found in the metal after fusion in the arc, the thermal characteristics of the electrode material before and after fusion as revealed by heating and cooling curves were determined. Samples of a $^3/_{16}$-in. electrode of type "A" and of the specimen A, which resulted from the fusion were used as material (composition in Tables IX and XII.)

TABLE XVII.—THE THERMAL CHARACTERISTICS OF ARC-FUSED IRON

		Ac3					Ar3			Ar2
Rate of Heating and Cooling, Deg. C., Sec.	Ac2, Maximum Deg. C.	Beginning	Maximum, Deg. C.	End	Maximum Temp., Deg. C.	Time Above A3, Min.	Beginning	Maximum, Deg. C.	End	Maximum, Deg. C.
Unfused Electrode										
0 15*	768	892	910	918	960	..	896	893	879	766
	765	897	911	916	960	..	895	891	879	766
Arc-Fused Metal †										
0.14	764	.	847	874	960	28	847	838	820	764
0.13	764		849	876	985	42	847	836	822	764
0.13	764		844	870	960	29	847	837	821	765
0.13	766		850	874	1,035	256	848	835	816	764

* Heated at rate of 0.16 deg. C. per sec., cooled 0.15 deg. C. per sec. for other specimens, the rate of cooling equaled the rate of heating.
† The same specimen was heated four times in succession, as shown. (Fig. 38)

In Fig. 168 are given the curves obtained which show the characteristic behavior of the arc-fused metal upon heating. The commonly used inverse-rate method was employed in plotting the data; the details of manipulation and the precautions necessary for the thermal analysis have already been described. In Table XVII are summarized the data shown graphically in the last cut.

The principal change to be noted which has resulted from

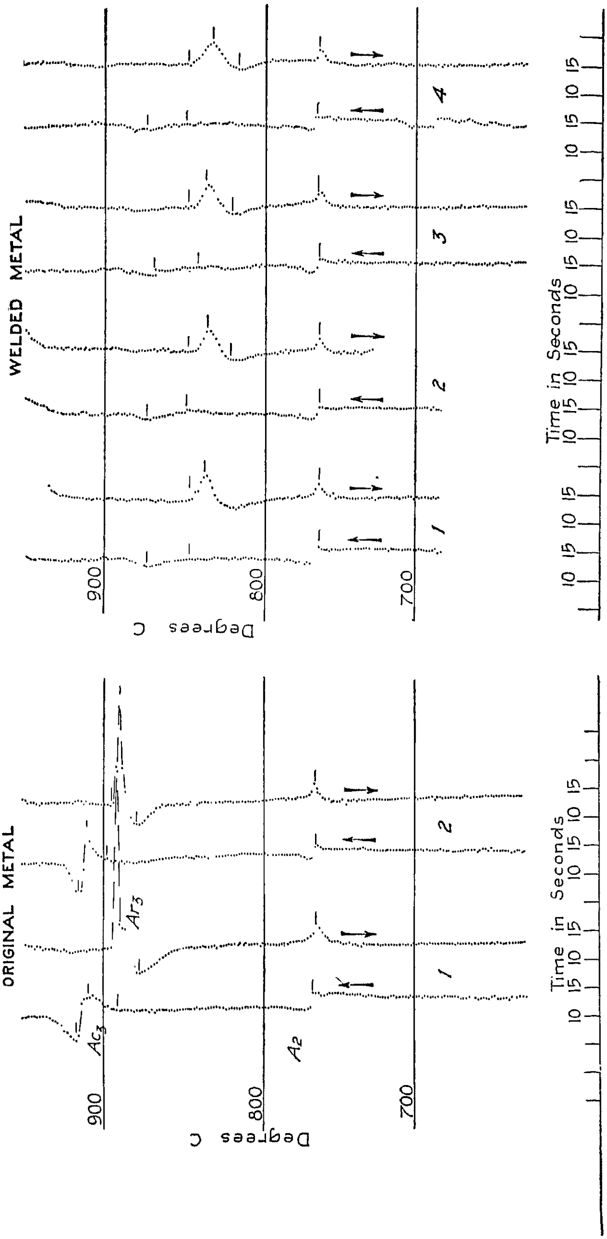


FIG. 168.—Curves Showing the Thermal Characteristics of Arc-Fused Iron.

The direction of the arrow indicates whether the curve is a heating or a cooling curve.

the arc-fusion of the iron is in the A_3 transformation. This is now very similar to the corresponding change observed in a very mild steel (e.g., approximately 0.15 per cent carbon). That the difference in the A_3 transformation of the arc-fused metal as compared with that of the original electrode is not due to an increase in the carbon content is evident from the lack of the sharp inflection of the A_1 transformation ("pearlite point") which would, of necessity, be found in a low carbon steel. No evidence of the A_1 change was observed for the arc-fused iron within the range of temperature, 150 to 950 deg C. The change in the character of the A_3 transformation is without doubt to be attributed to the influence of the increased nitrogen-content of the iron.

The specimen was maintained above the temperature of the A_3 transformation for a total period (four heatings) of 6 hr., the maximum temperature being 1,035 deg. C. The transformation apparently is unaffected by the long-continued heating, thus confirming the results described in the preceding section.

In discussing the properties of steel nitrogenized by melting it in nitrogen under pressure, Andrews states that it was found possible to extract almost entirely the small quantities of nitrogen by heating a specimen at 1,000 deg. C. *in vacuo* for periods of 1 to 6 hr. The metal used contained 0.16 per cent carbon and 0.3 per cent nitrogen. Thermal curves are given to show that there are no critical transformations in the material; the nitrogen suppresses them. They gradually reappear, however, as the nitrogen is removed by heating the material *in vacuo* at 1,000 deg. C. Several days' heating was required, however, to obtain an entirely degasified product, the carbon being removed also. A further statement is made that a steel of 0.6 per cent carbon content containing 0.25 per cent nitrogen can be brought back to the normal state of a pure steel only by several weeks' heating *in vacuo*.

The results of the thermal analysis add considerable confirmatory evidence to support the view that the plates existing in the arc-fused metal are due to the nitrogen rather than to carbon.

Summary.—Microscopic examination of bent pieces of arc-fused metal show that the metallic grains are inherently ductile,

even to a high degree. Grosser imperfections, however, are entirely sufficient to mask this excellence.

The view that the characteristic features observed in the structure of the arc-fused iron are due to the increased nitrogen content is supported by several different lines of evidence. These include the likeness of the structure of the material to that of pure iron which has been "nitrogenized," the similarity in the behavior of both arc-fused and nitrogenized iron upon heating, the evidence shown by thermal analysis of the arc-fused metal, together with the fact that, as shown by chemical analysis, the nitrogen content increases during fusion, while the other elements, aside from oxygen, decrease in amount. The characteristic form in which oxide occurs in iron, together with its behavior upon heating, renders the assumption that the oxide is responsible for the plates observed in the material a very improbable one.

Judged from the results obtained, neither type of electrode appears to have a marked advantage over the other. The use of a slight protective coating on the electrodes does not appear to affect the mechanical properties of the arc-fused metal materially in any way. The specimens were prepared in a manner quite different from that used ordinarily in electric-arc welding and the results do not justify any specific recommendations concerning methods of practice in welding.

CHAPTER XI

AUTOMATIC ARC WELDING

The automatic arc welding machine, made by the General Electric Co., Schenectady, N. Y., is a device for automatically feeding metallic electrode wire into the welding arc at the rate required to hold a constant arc length, says H. L. Unland in a paper read before the American Welding Society. Under these circumstances the electrical conditions are kept constant and the resulting weld is uniform and its quality is thereby improved. It is possible with this device to weld at a speed of from two to six times the rate attained by skilled operators welding by hand. This is partly due to the stability of the welding conditions and partly due to the fact that the electrode is fed from a continuous reel, thus eliminating the changing of electrodes. The automatic welding machine is adaptable to practically any form of weld from butt welding of plates to the depositing of metal on worn surfaces such as shafts, wheels, etc.

Everyone who has made any investigation of electric arc welding has noted the wide variation in results obtained by different welders operating, as nearly as can be determined, under identical conditions. This also applies to the operations of a single welder at different times under identical conditions. These variations affect practically all factors of welding such as speed of welding, amount of electrode consumed, etc. When indicating instruments are connected to an electric welding circuit, continual variations of considerable magnitude in the current and voltage of the arc are at once noticed. Considerable variation was found some years ago in the cutting of steel plates by the gas process and when an equipment was devised to mechanically travel the cutting torch over the plate a series of tests to determine the maximum economical speed, gas pressure, etc., for the various thickness of plate were made.

The result was that the speed of cutting was increased to as much as four or five times the rate possible when operating under the unsteady conditions incident to hand manipulation of the torch. Further, the gas consumption for a given cut was found to be decreased very greatly.

As a result of many experiences an investigation was started to determine what could be done in controlling the feed of the electrode to the electric arc in a metallic electrode welding circuit. An electric arc is inherently unstable, the fluctuations taking place with extreme rapidity. In any regulating device the sensitiveness depends on the percentage of variation from normal rather than on the actual magnitude of the values, since these are always reduced to approximately a common factor by the use of shunts, current transformers, or series resistances. The characteristics of practically all electric welding circuits are such that the current and voltage are inter-related, an increase in one causing a corresponding decrease in the other. Where this is the case it will generally be found that the percentage variation of the voltage from normal when taken at the customary arc voltage of 20, will be approximately twice the percentage variation in current. Further, an increase in arc voltage, other conditions remaining the same, indicates that the arc has been lengthened, thus giving the metal a greater opportunity to oxidize in the arc with a probability of reduction in quality of the weld. The automatic arc welding machine utilizes the arc voltage as the basis for regulating the equipment. The rate of feeding the wire varies over a wide range, due to the use of electrodes of different diameters, the use of different current values, etc., caused by details of the particular weld to be made. The simplest and most reliable method of electrically obtaining variations in speed is by means of a separately excited direct current motor. Thus the operation of this equipment is limited to direct current arc welding circuits, but these may be of any established type, the variations in characteristics of the welding circuits being taken care of by proper selection of resistors, coils, etc., in the control.

The Welding Head.—The welding head consists essentially of a set of rollers for gripping the wire and feeding it to the arc. These rollers are suitably connected through gearing

to a small direct-current motor, the armature of which is connected across the terminals of the welding arc. This connection causes the motor to increase in speed as the voltage across the arc increases due to an increase in the length of the arc and to decrease in speed as the voltage decreases, due to a shortened arc. A small relay operating on the principle of a generator voltage regulator is connected in the field circuit of the motor which assists in the speed control of the motor as the arc voltage varies. Rheostats, for regulating and adjusting the arc voltage, are provided by means of which the equipment can be made to maintain steadily an arc of the desired length and this value may be varied from over twenty to as low as nine volts. No provision is made in the machine for adjustment of the welding current since the automatic operation is in no way dependent on it. The welding current adjustment is taken care of by the control panel of the welding set. This may be either of the variable voltage or constant potential type but it is necessary to have a source of constant potential to excite the fields of feed motor. It may be possible to obtain this excitation from the welding circuit, but this is not essential. The voltage of both the welding and constant potential circuits is immaterial, provided it is not too high, but these voltages must be known before the proper rheostats can be supplied.

On account of the great variation in conditions under which this welding equipment may be used it is provided with a base which may be bolted to any form of support. It may be held stationary and the work traveled past the arc or welding head may be movable and the work held stationary. These points will be dictated by the relative size of the work and the head and the equipment which may be available. Provision must be made for traveling one or the other at a uniform speed in order to carry the arc along the weld. In the case of straight seams a lathe or planer bed may be utilized for this purpose and for circular seams a lathe or boring mill may be used. In many cases it will be found desirable to use clamping jigs for securely holding the work in shape and also to facilitate placing in position and removing from the feeding mechanism.

In Fig. 169, the welding head is shown mounted on a special

device for making circular welds. The work table is driven through a worm and worm gear by means of a separate motor.

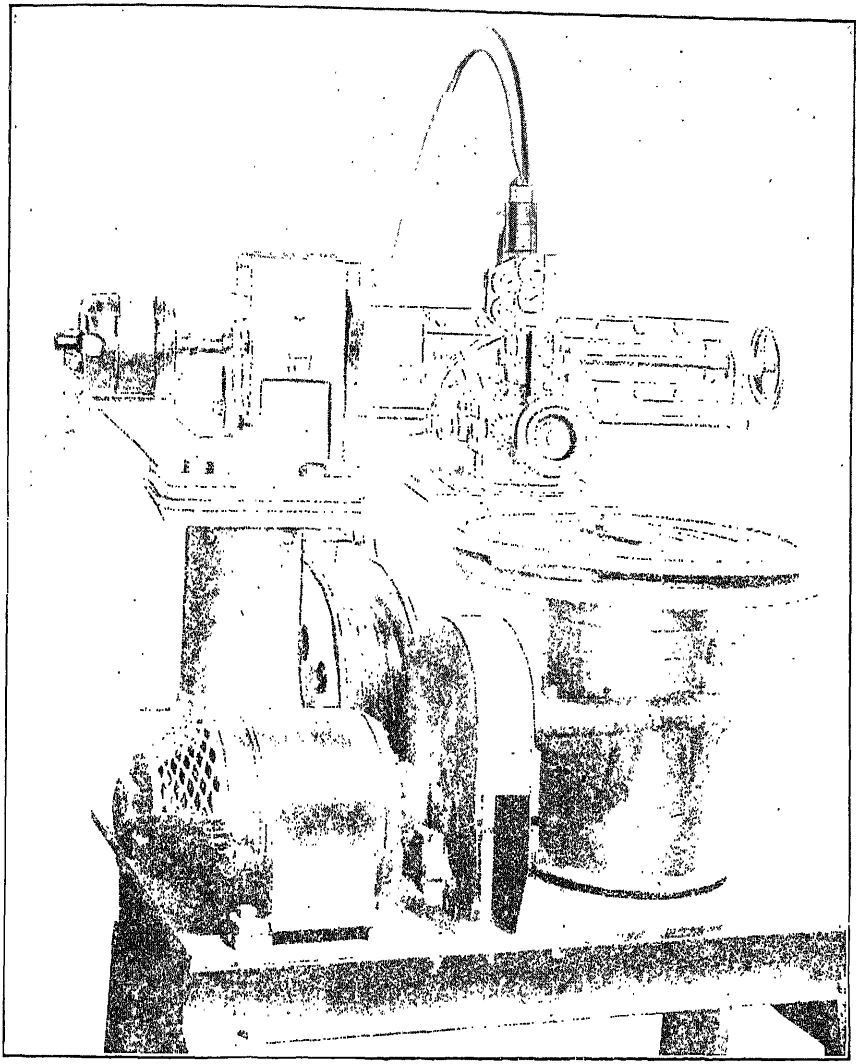


FIG. 169.—Special Set-Up of Machine for Circular Welding.

The welding head may be led along the arm by means of the handwheel, and it may be tilted at an angle of 45 deg.

both at right angles to the line of weld and also parallel to the line of weld. Fig. 170 shows the building up of a shaft, the work being mounted on lathe centers and the welding head placed on a bracket clamped to saddle.

Fig. 171 shows a simplified diagram of the control of the feed motor. In this cut *A* is the regulating rheostat in the motor field circuit controlled by the arc voltage regulator *G*; *B* is the adjusting rheostat in the motor field circuit; *F*

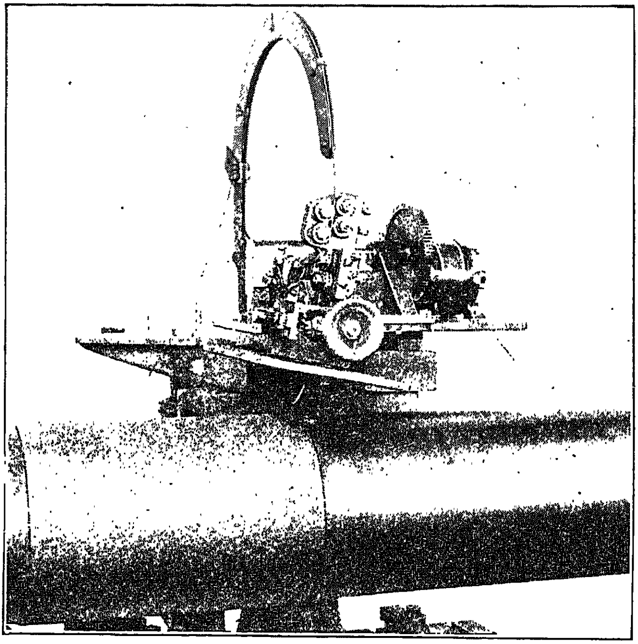


FIG. 170.—Set-Up for Building up a Shaft.

indicates the feed motor field winding; *M* the feed motor winding; *D* is the resistance in the motor armature circuit to adjust the speed when starting the feed motor before the arc is struck. The open-circuit voltage of the welding circuit is ordinarily considerably higher than the arc voltage. This resistance *D* is short circuited by contactor *X* when the arc is struck. The arc voltage regulator *G* maintains constant arc voltage by varying the motor field strength through resistor *A*. The regulator is adjusted to hold the desired voltage by the rheostat

C. Permanent resistance E is in series with the over-voltage relay H, to compensate for the voltage of the welding circuit. Over voltage relay H holds open the coil circuit of the regulator G until the electrode makes contact in order to protect the coil from burning out.

Observation of indicating meters on the control panel show that the current and voltage are practically constant, but it should be remembered that all indicating meters have a certain amount of damping which prevents observation of the variations which are extremely rapid or of small magnitude. The resultant value as read on the instrument is the average value. Oscillographs taken with short arcs show that notwithstanding the fact that the indicating meters show a constant value, a

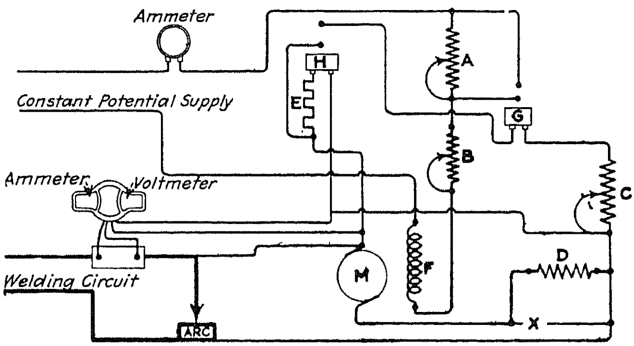


FIG. 171.—Simplified Diagram of Control of Feed Motor.

succession of rapid short circuits is continually taking place, apparently due to particles of the molten wire practically short-circuiting the arc in passing from the electrode to the work. This is indicated by the fact that the voltage curve fell to zero each time, and accompanying each such fluctuation there was an increase in the current. It was found that with the shorter arc the frequency of occurrence of these short-circuits was considerably higher than was the case when the arc was increased in length. To all appearances the arc was absolutely steady and continuous and there was no indication either by observation of the arc itself or of the instruments that these phenomena were occurring.

Some Work Performed By the Machine.—The principal field for an automatic arc welding machine is where a consider-

able amount of welding is required, the operations being a continuous repetition of duplicate welds. Under these conditions one can economically provide jigs and fixtures for facilitating the handling of the work and the clamping. Thus can be reaped the benefit of the increased speed in the actual welding which would be lost if each individual piece had to be clamped and handled separately.

Examples of different jobs done with this machine, using various feeding and holding methods, are shown in the accompanying cuts. Fig. 172 is a worn pulley seat on an electric motor shaft built up and ready to be re-turned to size.

It is possible to build up pulley and pinion seats, also worn bearings, without removing the armature or rotor from the

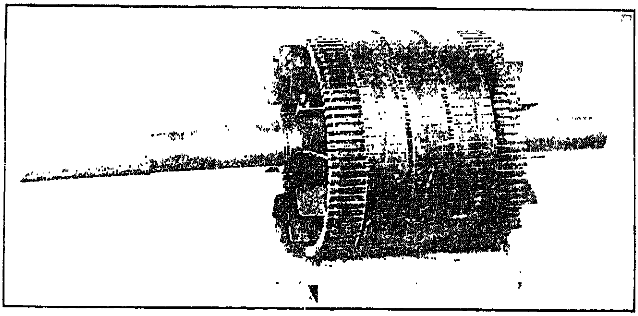


FIG. 172.—Worn Motor Shaft Built Up.

shaft and in practically all cases without removing the windings due to the concentration of the heat at the point of the weld. On shafts of this kind, 3 to 4 in. in diameter, the figures are: current 115 amp.; arc voltage 14; electrode $^3/_{32}$ in. in diameter; travel, 6 in. per min.; rate of deposit about 2.1 lb. per hour.

Similar work on a 14-in. shaft where the flywheel seat 21 in. long was turned undersize, was as follows: metal about $^3/_{16}$ in. deep was deposited over the undersize surface, using current, 190 amp.; arc voltage 18; electrode $\frac{1}{8}$ in. diameter; travel 4 in. per min.; rate of deposit, about 2 lb. per hour; welding time, 16 hr.; machining time, 4 hr.

Fig. 173 shows worn and repaired crane wheel flanges. These are easily handled by mounting on a mandrel in a lathe,

and placing the welding machine on a bracket bolted to the cross-slide or the saddle. On wheels of this type 22 in. in diameter, the time taken to weld by hand would be about 12 hr. and by machine 2 hr.; machining time 4 hr.; approximate cost by hand welding \$9; by machine \$4.

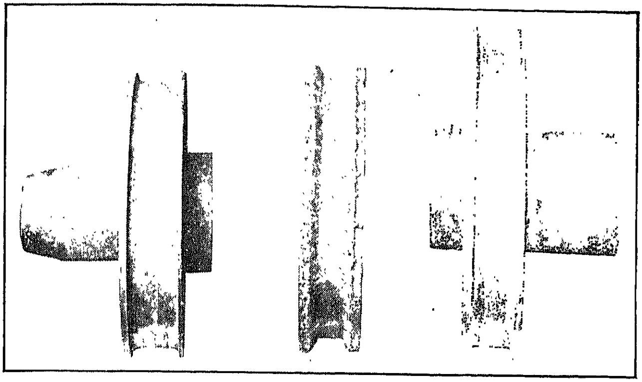


FIG. 173.—Worn and Repaired Crane Wheels.

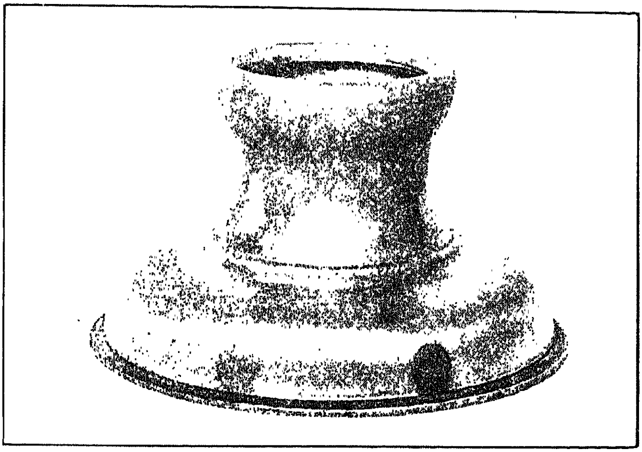


FIG. 174.—Welded Automobile Hub Stampings.

Fig. 174 is an automobile wire wheel hub stamping, to which a dust cover was welded as shown. Joint was between metal $^1/_{16}$ and $^3/_{16}$ in. thick. Current 100 amp.; arc voltage, 14; travel 10 in. per min.; electrode $^3/_{32}$ in. diameter.

Fig. 175, welded automobile rear-axle housing, $^3/_{16}$ in. thick; current 120 amp.; arc voltage 14; travel 6 in. per min.; electrode diameter $^3/_{32}$ in.

Fig. 176, welded tank seam; metal $\frac{1}{8}$ in. thick; current 140 amp.; arc voltage 14; travel, 6 in. per min.; time for welding ten tanks by hand, 4 hrs. 40 min.; by machine, 2 hrs.

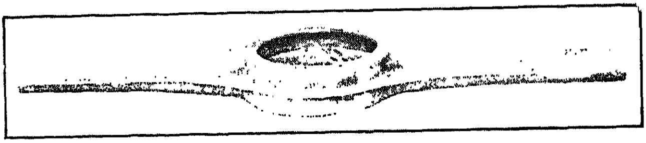


Fig. 175.—Welded Rear-Axle Housing.

Tables XVIII and XIX give an idea of the speed of welding which may be expected, but it should be borne in mind that these figures are actual welding speeds. It is necessary to have the material properly clamped and supported and to have it travel past the arc at a uniform speed. In some cases the

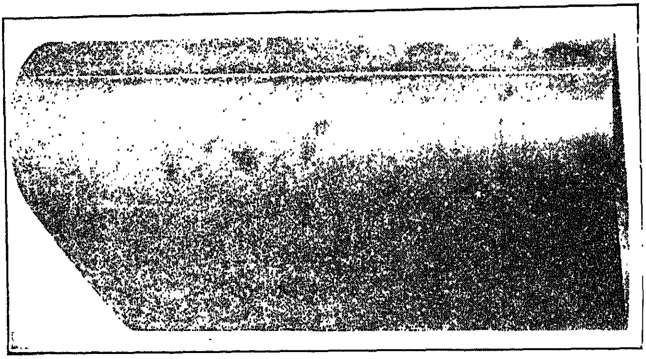


Fig. 176—Welded Straight Tank Seam.

figures given have been exceeded and under certain special conditions it may be desirable to use lower values than those given.

Table XVIII.—Seam Welding

Thickness in Inches	Amperes	Speed, Inches Per Minute
0.040	45 to 50	20 to 30
1/16	50 to 80	15 to 25
1/8	80 to 120	6 to 12
3/16	100 to 150	4 to 6

TABLE XIX—BUILDING UP (WHEELS OR SHAFTS)

Diameter or Thick., In.	Electrodes, Dia., In.	Amperes	Speed, In. per Min.	Lb. Deposit Per Hour
Up to 1″	$^1/_{16}$	60 to 90	11 to 13	1.04–1.56
Up to 3″	$^5/_{32}$	90 to 120	6 to 8	1.59–2.1
Over 3″	$^1/_8$	120 to 200	4 to 6	2.5 –4.5

A SEMI-AUTOMATIC ARC-WELDING MACHINE

A paper on "Welding Mild Steel," by H. W. Hobart, was read at the New York meeting of the American Institute of Mining and Metallurgical Engineers in 1919. In discussing this paper Harry D. Morton, of the Automatic Arc Welding Co., Detroit, brought out some interesting things relating to Automatic Arc Welding:

"The generally accepted theory of the electric arc is that part of the electrode material is vaporized, and that this vaporous tube or column forms a path for the electric current. As a result of the vaporous character of the current path, all arcs are inherently unstable; and the maximum of instability is no doubt found in that form of arc employed for metallic-electrode welding purposes. We here have, in conjunction with the natural instability characteristic of all arcs rapidly fusing electrode materials and the disturbing effect of the constant passage through the arc of a large quantity of molten metal to form the weld. This molten metal must pass through the arc so rapidly that it will not be injured or materially contaminated; otherwise the weld will be useless. Prima facie, the combination of these unfavorable conditions would seem to justify fully the skepticism of most electrical engineers as to the possibility of affecting such control of the metallic arc as to permit of uniformity and continuity in welding results. In addition, there is another and more important factor, and one that seriously mitigates against this desired uniformity and continuity; namely, the personal equation of the operator. The consensus of opinion, so far as is known to the writer, seems to be that about 95 per cent. of the welding result is dependent on the skill of the operator and that at least six months' practice is necessary to acquire reasonably satisfactory proficiency.

"As the result of thousands of observations of welds produced automatically (wherein the personal equation is entirely eliminated), the writer inclines toward the theory that the molten electrode material passes through the arc in the form of globules; and that where $\frac{1}{8}$-in. electrode material is employed with a current of about 150 amp. these globules are deposited at the rate of approximately two per second. The passage through the arc of each globule apparently constitutes a specific cause of instability in addition to those existent with slowly consumed electrodes. This hypothesis seems to be borne out by ammeter records, typical specimens of which appear in Fig. 177, together with the fact that the electrode

fuses at the rate of about 0.20 in. per sec. Moreover, the globules appear to be approximately equal in volume to a piece of wire 0.125 in. in diameter and 0.10 in. long.

"Assuming this theory to be correct, to maintain a uniform arc length in manual welding, the operator must feed the electrode toward the work

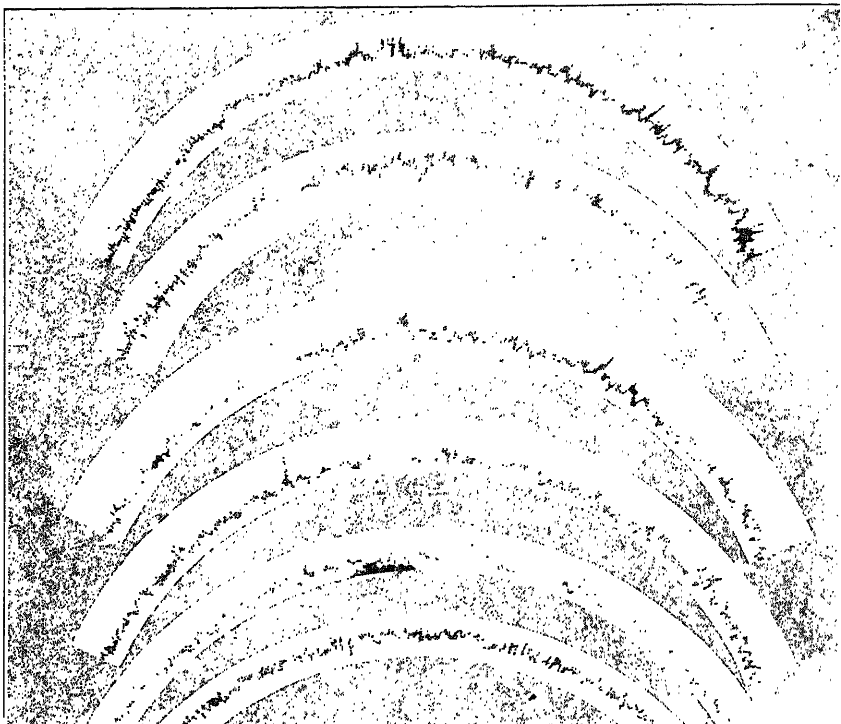


FIG. 177.—Typical Ammeter Charts of Operation of Morton Automatic, Metallic-Electrode Arc-Welding Machine.

Average Time about 1 Min. 45 Sec.

at the rate of 0.10 in. upon the deposition of each globule; in other words, 0.10 in. twice per second, a synchronism beyond human attainment. Simultaneously with such feeding, the arc must be moved over the work to melt the work material, distribute the molten electrode material, and form the weld. Inasmuch as the effect of the arc is highly localized,

it is reasonable to suppose that different parts of the welding area present relatively wide variations in respect to temperature, fluidity, and conductivity of the molten mass—controlling factors not within the ken of the human mind. The situation is further complicated by the facts that neither the welding wire nor the work material is uniform in fusibility or in conductivity, and that the contour of the work varies continually as its surface is fused and the molten metal is caused to flow. The belief is general that a very short arc is productive of the best welding results; but it is an arc of this character that makes the greatest demands on the skill of the operator, for there is always the danger that the electrode will actually contact with the work and destroy the arc.

"As the fusing energy of the arc varies widely with fluctuations in the arc length and as the uniformity of the weld depends on the constancy and correctness of this fusing energy, it seems remarkable that operators are able ever to acquire such a degree of skill as to enable them to produce welds that are even commercially satisfactory. Further, so far as the writer is informed, there is no means, other than such as would be destructive, for determining whether a completed weld is good or bad. The logical solution appeared to be the elimination of the personal equation and the substitution therefor of means whereby tendencies toward variations in the arc would be caused automatically to correct themselves, just as a steam engine, through the action of its governor, is caused to control its own speed.

Methods of Mechanically Stabilizing and Controlling the Arc.—Our efforts for a number of years have been directed toward stabilizing and controlling the metallic arc, and applying such stabilizing and controlling means to two general lines of welding machinery: (1) Machines for automatically feeding the electrode wire, with reference to the work, and producing simultaneously therewith relative movement between the wire and the work, and (2) what, for lack of a better term, might be called a semi-automatic machine, in which the feeding of the electrode and the control of the arc are accomplished automatically but the traversing of the electrode with reference to the work is manually effected by the operator, permitting him the exercise of judgment with reference to the quantity of metal to be deposited in various parts of the groove. The automatic machine has been in successful operation for a long period and the semi-automatic machine for about five months. While the goal was not attained without many difficulties and a great expenditure of time and money, the results have been surprisingly successful.

"Because of the lack of any definite data as to what actually occurs in this form of arc, or why it occurs, due, no doubt, to the impossibility of differentiating between phenomena that are characteristic of the arc and phenomena due to the personal equation of the welder, it seemed logical that the initial step should be to so environ the arc that it would not be subject to erratic extraneous influences, to the end that reasonably definite determinations might be substituted for scientific speculation. In the design and construction of the machines, great care was exercised to minimize the possibility of mechanical defects that might lead to

erroneous conclusions. Starting with the assumption that the work could only be based on open-minded observation of the behavior of the arc under machine control, an automatic welding machine was built in which was incorporated the greatest possible number of adjustable features, in order that, if necessary, it might be possible to wander far afield in the investigations. This adjustability has proved invaluable in that it has permitted logical, consistent, and sequential experimenting over a very wide range of conditions. Working under these favorable circumstances, there were soon segregated a few clearly demonstrable facts to serve as a foundation for the structure, which has since been added to, brick by brick, as it were.

"Efforts have been directed toward the practical rather than the scientific aspect of the subject. The operation of the automatic machines has brought to light many curious and interesting phenomena, some of which appear to negative conclusions heretofore formed which have been predicated upon observations made in connection with manual welding. It is hoped that these and other phenomena, which can thus be identified as purely arc characteristics, will be the subject of profitable scientific investigation when time is available for this purpose.

"In the five forms of machines made in the course of the development, the welding wire is automatically fed to the arc; and, in the first four machines, the relative movement between the work and the welding wire is automatically and simultaneously effected. Early in his investigations, the writer concluded that a substantial equilibrium must be maintained between the fusing energy of the arc and the feeding rate of the welding strip; and it soon became evident that if the welding strip is mechanically fed forward at a uniform rate equal to the average rate of consumption with the selected arc energy, this equilibrium is actually maintained by the arc itself, which seems to have, within certain circumscribed limits, a compensatory action as follows: When the arc shortens, the resistance decreases and the current rises. This rise in current causes the welding strip to fuse more rapidly than it is fed, thereby causing the arc to lengthen. Conversely, when the arc lengthens, the resistance increases, the current falls, the welding strip is fused more slowly than it is fed, and the moving strip restores the arc to its normal length.

"While this compensatory action of the arc will maintain the necessary equilibrium between the fusing energy and the feeding rate under very carefully adjusted conditions, this takes place only within relatively narrow limits. It was very apparent that, due to variations in the contour of the work, and, perhaps, to differences in the fusibility or conductivity of the welding strip or of the work, the range of this self-compensatory action of the arc was frequently insufficient to prevent either contacting of the welding strip with the work or a rupture of the arc due to its becoming too long. The problem that arose was to devise means whereby the natural self-compensatory action of the arc could be so greatly accentuated as to preclude, within wide limits, the occurrence of marked arc abnormalities. There was ultimately evolved, by experiment, such a relation between the fusing energy of the arc and the feeding rate of the welding strip as to

give the desired arc length under normal conditions; and tendencies toward abnormalities in arc conditions, no matter how produced, were caused to

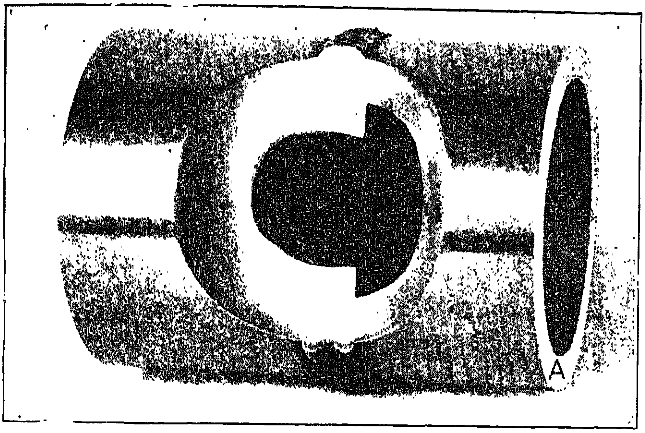


FIG. 178.—Piloted Cup Automatically Welded by Metallic-Electrode Arc Process to Tube to Form 75-MM. Shrapnel Shell.

Analysis of Electrode Material: Silicon, 0.02 Per Cent; Sulphur, 0.013 Per Cent; Phosphorus, 0.07 Per Cent; Manganese, Trace; Carbon, 0.07 Per Cent; Aluminum, 0.038 Per Cent.

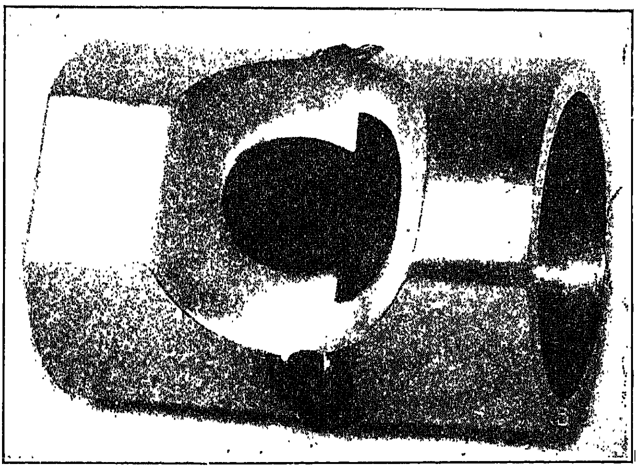


FIG. 179.—Piloted Cup Automatically Welded by Metallic-Electrode Arc Process to Tube to Form 75-MM. Shrapnel Shell.

Analysis of Electrode Material: Silicon, 0.03 Per Cent; Sulphur, 0.049 Per Cent; Phosphorus, 0.008 Per Cent; Manganese, 0.31 Per Cent; Carbon, 0.28 Per Cent.

bring into operation compensatory means for automatically, progressively, and correctively varying this relation between fusing energy and feeding

rate, such compensatory means being under the control of a dominant characteristic of the arc. In their ultimate forms, the devices for effecting the control of the arc are simple and entirely positive in action, making discrepancies between fusing energy and feeding rate self-compensatory throughout widely varying welding conditions. For instance, the shrapnel shell shown in Fig. 178 was automatically welded with wire differing greatly in chemical constitution from that used on the shell shown in Fig. 179 (see analyses), yet no change was made in either the mechanical or the electrical adjustments. The radically different welding conditions were compensated for solely by the operation of the automatic control. The electrode materials used for the shells shown in Figs. 180 and 181

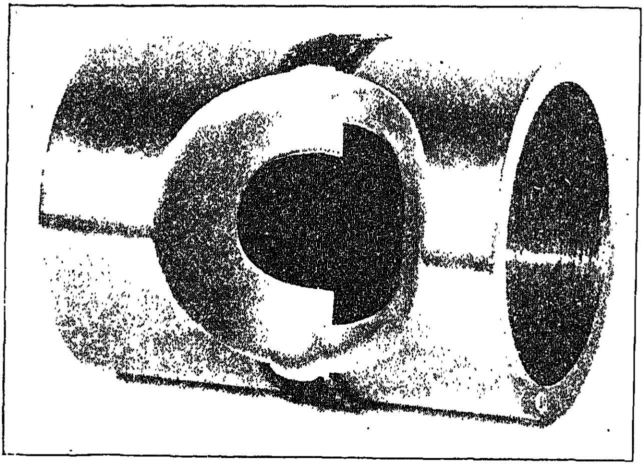


Fig. 180.—Piloted Cup Automatically Welded by Metallic-Electrode Arc Process to Tube to Form 75-MM. Shrapnel Shell.

Analysis of Electrode Material: Silicon, 0.02 Per Cent; Sulphur, 0.032 Per Cent; Phosphorus, 0.008 Per Cent; Manganese, 0.20 Per Cent; Carbon, 0.18 Per Cent.

differed so greatly from those employed respectively in welding the shells shown in Figs. 178 and 179 that a change in the relation between fusing energy and feeding rate had to be made manually. After this adjustment was made, the shells were welded with their respective electrodes, which varied widely in their chemical constitution, without further manually changing either the mechanical or the electrical conditions.

"In a recent test of the semi-automatic machine, shown in Fig. 182, successful welds were made under the condition that the impressed voltage of the welding generator was changed throughout a range of from 50 to 65 volts, without necessitating any manual adjustment. The only observable effects of the wide variations in the supply voltage were slight differences in the arc length. In short, the compensatory action of the control has proved effective over a wide range of welding conditions, not only as to

the electrical supply and chemical constitution of both electrode and work materials, but also as to extensive variations in the contour of the work and in many other particulars. This makes it seem apparent that the machines do not represent merely successful laboratory experiments but are suited to the requirements of actual commercial welding.

"One particularly interesting observation resulting from the experiments is that the angle of inclination of the electrode with reference to the work is very important. An angular variation of 5 deg. will sometimes determine the difference between success and failure in a weld. About 15 deg. from the perpendicular works well in many cases. In welding some materials, the electrode should drag, that is, point toward the part already welded rather than toward the unwelded part of the seam.

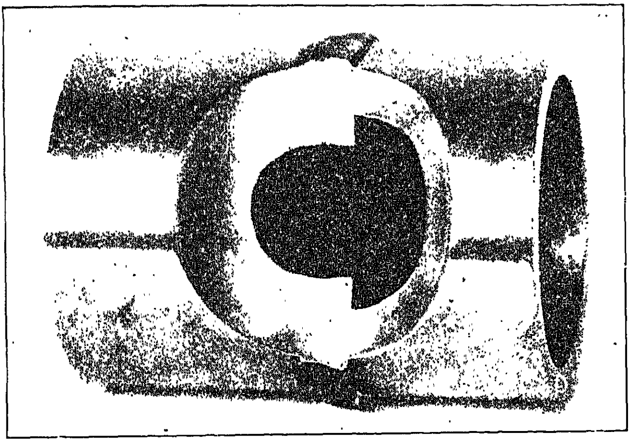


FIG. 181.—Piloted Cup Automatically Welded by Metallic-Electrode Arc Process to Tube to Form 75-MM. Shrapnel Shell.

Analysis of Electrode Material: Silicon, 0.04 Per Cent; Sulphur, 0.016 Per Cent; Phosphorus, 0.058 Per Cent· Manganese, None; Carbon, 0.24 Per Cent.

"While it has been customary in some welding systems to provide means whereby extra resistance is inserted in series with the arc at the instant of the initial contact which starts the flow of current, the resistance being automatically cut out upon the striking of the arc, experience with the automatic machines indicates that this is quite unnecessary.

"Early in the experiments, it was noted that in many cases there was a decidedly marked affinity between particular electrode materials and particular work materials. A slight change in either element affects the degree of this affinity. While it has invariably been possible to control and maintain the arc and weld continuously, in some instances incompatibility between electrode material and work material has been productive of interesting phenomena. For instance, the combination of work material (steel of about 0.45 per cent. carbon content) and the particular electrode

material used in Fig. 178 produced an arc that was remarkably quiet and free from sputtering. Throughout the weld, this arc was suggestive of the quiet flame of a candle or lamp, the erratic behavior that we are accustomed to associate with the ordinary metallic arc being absent. The effect is reflected in the uniform deposition of the welding material.

"On some classes of work material Bessemer wire, which some authorities claim cannot be used in metallic-electrode arc welding, produces an arc

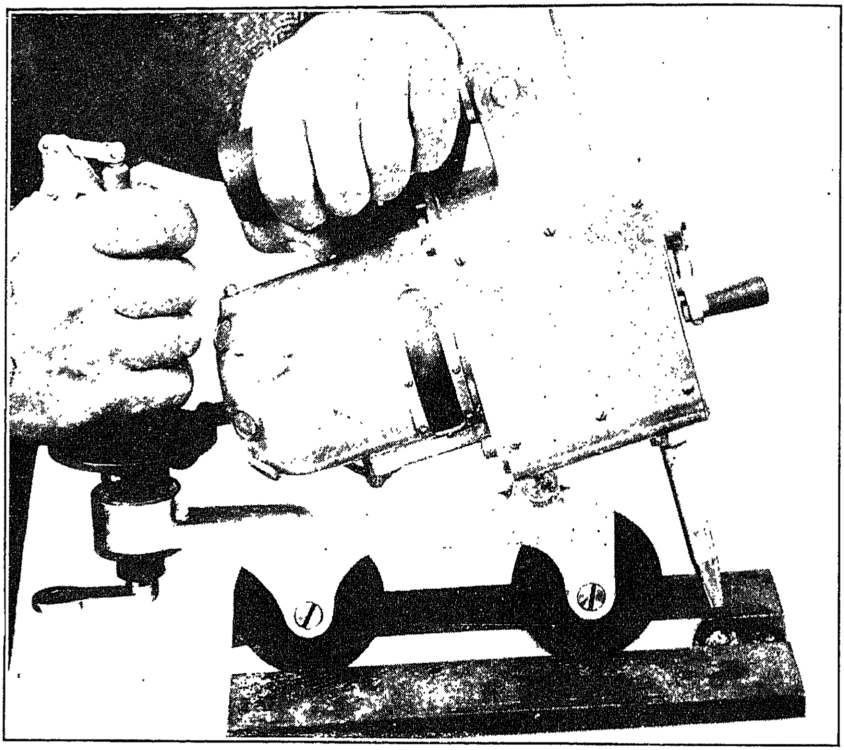


Fig. 182.—Morton Semi-Automatic Metallic-Electrode Arc-Welding Machine.

The Electrode is automatically fed to the arc, which is automatically maintained while the machine is manually moved along the groove to be welded.

and a weld very satisfactory in appearance. On other work material, the Bessemer wire arc is violently explosive. These explosions are accompanied by quite sharp reports and the scattering over some considerable distance of globules of molten metal frequently $^3/_{32}$ in. or more in diameter. Under certain other conditions, apparently growing out of incompatibility between the work material and the electrode material, the oxygen flame accompanying the arc gyrates very rapidly about the arc, producing an effect suggestive of the 'whirling dervish.'

"From both the practical and the scientific points of view, the writer has experimented quite extensively with varying combinations of work material and electrode material. Throughout all the differences in arc conditions, many of which palpably accentuate the natural inclination toward instability, the control has so operated as to justify the expression 'the arc persists.'

"Generally speaking, the Swedish and Norway iron wires seem to produce more quiet arcs and, possibly, a more uniform deposition of electrode material, than do wires of other classes. These welds may perhaps be found to be slightly more ductile than those made with wires of other chemical composition. On the other hand, these soft wires, although undoubtedly of relatively high fusibility, do not, for some reason, seem to produce an arc that cuts into some work material as deeply as might be desired, nor as deeply as do the arcs formed with certain other kinds of wire. Considered from every angle, the writer is disposed to regard the Roebling welding wire as the best he has thus far tested for use on mild steel. The wire produces a reasonably quiet arc which seems to cut into the work to more than the ordinary depth, while, at the same time, the electrode material is fused with more than average rapidity—thus increasing the welding rate.

"While scientists will no doubt ultimately arrive at the correct hypothesis for solving the problem of why one combination of electrode material and work material is productive of better results than can be obtained with another combination, the writer's conclusion is that, with the data at present available, the determinations must be made by actual experimenting —having in mind the qualities desired in the particular weld, such as ductility, tensile strength, elongation, and elastic limit. Inasmuch as it is possible, with the automatic machine, to maintain arc uniformity with practically any kind of electrode material and to produce welds which, under low magnification, at least, appear to be perfect, and which respond favorably to ordinary tests such as bending, cutting and filing, it is reasonable to conclude that proper selection of electrode material will be productive of perfect welds on any kind of work material. To date, no steel has been tested on which apparently satisfactory welds could not be made. High-speed tungsten steel has been successfully welded to cold-rolled shafting, using Bessemer wire as electrode material, as is shown in Fig 183. Ordinary steels varying in carbon content from perhaps 0.10 to 0.55 per cent. have been welded with entire success.

"Because of the fact that the complete welding operation has been automatic and may be continued for a considerable length of time, say 5 min., an exceptional opportunity has been afforded for close concentration upon the study of the appearance of the arc. What seems to occur is that the molten metal in the crater is in a state of violent surging, suggestive of a small lake lashed by a terrific storm. The waves are dashed against the sides of the crater, where the molten metal of which they are composed quickly solidifies. The surgings do not seem to synchronize with nor to be caused by the falling of the globules of molten metal into the crater, but seem rather to be continuous. They give the impression

that the molten metal is subjected to an action arising from the disturbance of some powerful force associated with the arc—such, for instance, as might result from the violent distortion of a strong magnetic field. Altogether, the crater phenomena are very impressive; and the writer hopes ere long to be able to have motion pictures made which, when enlarged, should not only afford material for most fascinating study, but also throw light upon some of the mysterious happenings in the arc.

So far, electrode wires $\frac{1}{8}$ in. in diameter have been chiefly used in the machines. Successful welds have been made with current values ranging from below 90 to above 200 amp., at impressed voltages of 40, 45, 50,

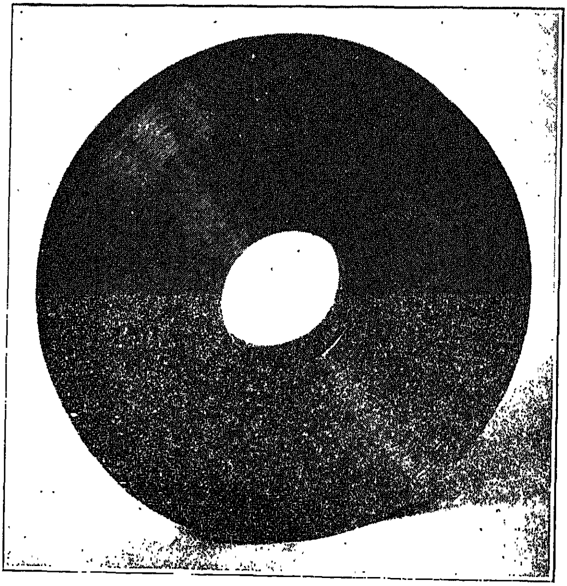


FIG. 183.—Tungsten High-Speed Ring Automatically Welded by Metallic-Electrode to Cold-Rolled Core to Form Milling-Cutter Blank.

55, 60, 65 and 80. Under these varying conditions, the voltage across the arc has been roughly from 16 to 22. The machines have thus far been run only on direct current. Inasmuch as it is possible, by electrical and mechanical adjustments, to establish nearly any arc length that may be found to be most desirable for a particular class of work, and as the control system will maintain substantially that arc length indefinitely, the fully automatic type of machine is nearly as certain in operation as a lathe, drilling machine, or any other machine tool.

"The tool shown in Fig. 182 weighs about $10\frac{1}{4}$ lb. The operator draws the tool along the groove to be welded at such a rate as will result in the deposition of the quantity of metal required to satisfactorily effect the weld. This tool is intended for use in the many restricted spaces en-

countered in ship welding, which would be relatively inaccessible to a fully automatic machine. In its use, the skill required by the operator is reduced to a minimum. After one man had practised with the welding tool for not more than 2 hr., the opinion was expressed that it would require six months to train a welder to such a degree of proficiency as to enable him to make a weld equally good in appearance.

"Mr. Hobart, says 'There is always a matter of a 0.10 in. or more between the end of the welding rod and the work.' While undoubtedly it is difficult, if not impossible, to maintain in manual welding an arc shorter than this, the writer has frequently, with the automatic machines, made continuous and strikingly good welds with arcs of much less length. In fact, in some cases there has been continuously maintained an arc so short that there hardly seemed to be any actual separation. The writer

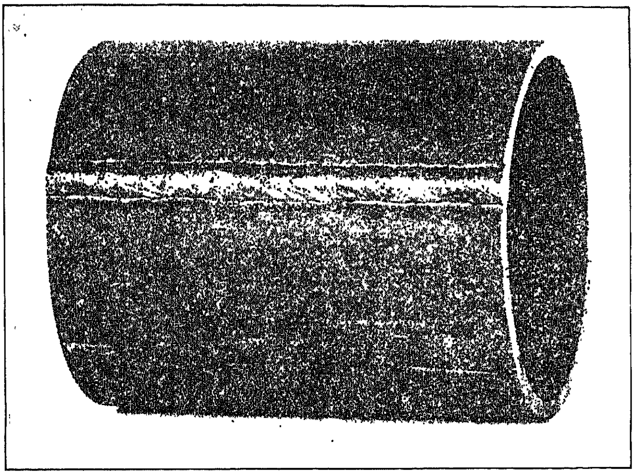


FIG. 184.—No. 11 Gage Steel Tubing Automatically Welded by Metallic-Electrode Arc Process at the Rate of One Foot per Minute.

has even wondered whether, under these conditions, there was not a close approach to casting with a continuous stream of fluid metal acting as the current conveyor in lieu of or in parallel with the usually assumed vapor path. The work that has been done indicates that under automatic control much shorter arcs can be utilized than have hitherto been deemed possible, and with probable marked gain in quality of work in some instances; also, that there is much to be learned as to the mode of current action and current conduction in such an arc.

"With the automatic machine, black drawing steel 0.109 in. thick has been welded at the rate of 22 in. per minute. A Detroit manufacturer welded manually with oxy-acetylene at the rate of four per hour a large number of mine floats 10 in. in diameter, made of this material. The automatic machine made the welds at the rate of forty per hour. Liberty

motor valve cages $2\frac{3}{4}$ in. in diameter have been welded to cylinders in 36 sec., as against about 5 min. required for manual welding. No. 11 gage steel tubing, shown in Fig. 184, has been welded, with an unnecessarily

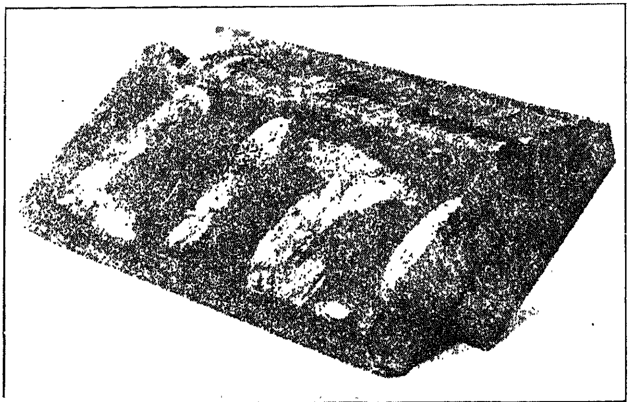


FIG. 185.—Two $\frac{1}{2}$-in. Ship Plates Automatically Welded by Metallic-Electrode Arc Process to Form Lap Joint.

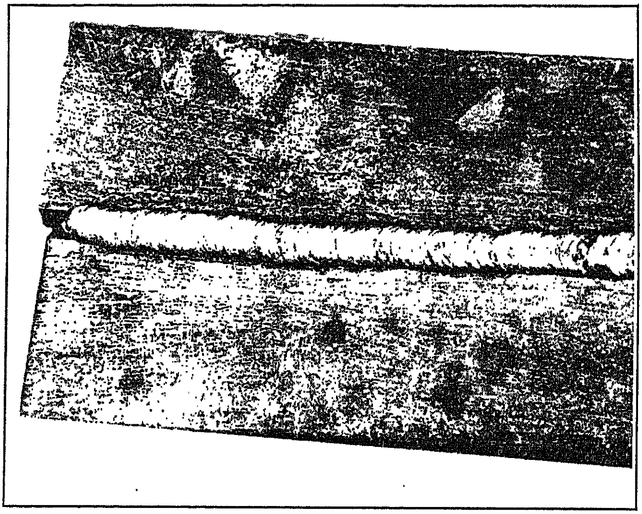


FIG. 186.—Two $\frac{1}{2}$-in. Ship Plates Automatically Welded by Metallic-Electrode Process to Form Butt Joint.

heavy deposit of metal, at the rate of 1 ft. per minute. The productive capacity of the machines so far made has been from three to ten times that of manual welding methods, depending on the thickness of the work

material; the difference in favor of automatic welding varies inversely as such thickness. The writer is now designing an improved type of machine for use especially on heavy work. with which machine it is expected to be able automatically to lapweld ½-in. ship plates, in the manner shown in Fig. 185, at the rate of 15 ft. per hour. One of the largest shipbuilding concerns in the United States reports that the general average of all its manual welders on this class of work is from 1 ft. to 18 in. per hour. Other specimens of automatic welding on ship plates are shown in Figs. 186 and 187.

"Bare wire only has been used in the automatic machines; and the results obtained seem to indicate that the covering of the electrodes is an expensive superfluity. If the chief advantage of the covered electrode lies in the ability of the operator to maintain a very short arc, an arc equally short and possibly shorter can be continuously maintained by the automatic machine using bare electrodes.

"No attempt has thus far been made to use the automatic machines

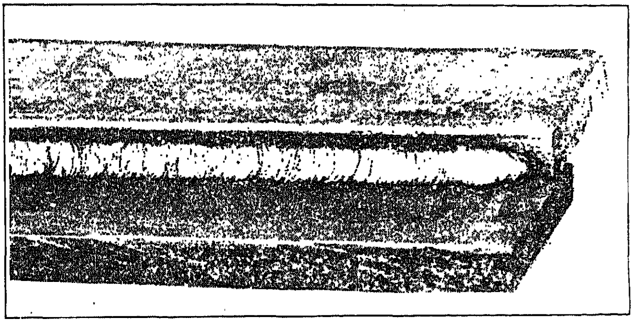


FIG. 187.—Two ½-in. Ship Plates Automatically Welded by Metallic-Electrode Arc Process, Showing First of Three Layers to Form Lap Joint.

on overhead work. The welds made with the fully automatic machine have been of three kinds. the usual longitudinal form, annular about a horizontal axis, and annular about a vertical axis.

"As far as the maintenance of arc uniformity and the apparent character of the welds are concerned, the writer has repeatedly welded with wire showing evidence of pipes and seams, as well as with rusty wire and with wire covered with dirt and grease. In this connection it may be said that no pains is ever taken to remove rust, scale, or slag from the work material—even where welds are superimposed. Apparently under uniform conditions of work traverse, arc length, and electrode angle of inclination, such as are possible in the automatic machine, impurities vanish before the portion of the work on which they occur reaches the welding area of the arc.

"The writer is fully convinced that with the use of the automatic machine, ductility, like other physical properties in the weld, can be controlled by proper selection of electrode wire. in conjunction with electrical

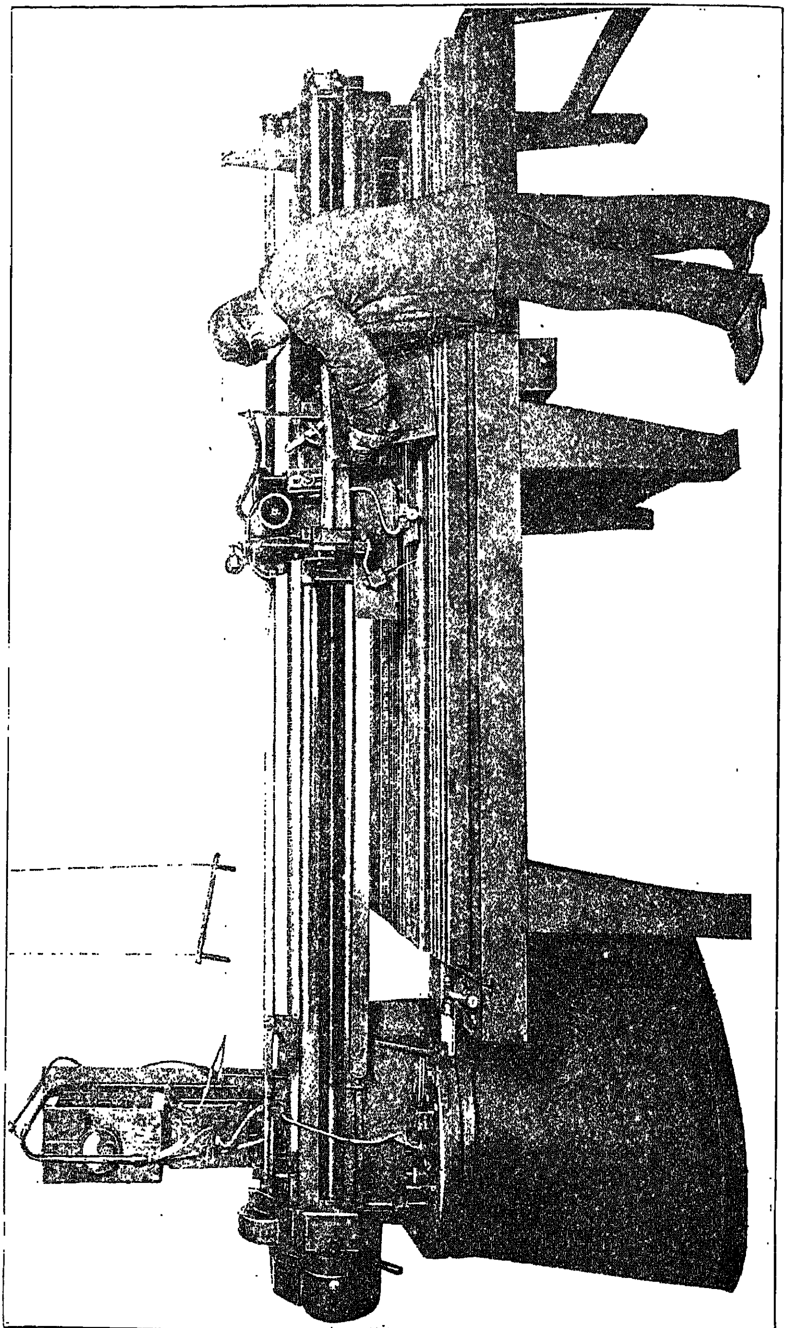


FIG. 188.—Carbon Electrode Arc Seam-Welding Machine.

and mechanical adjustments best suited to the particular purpose in view. Automatic welds have repeatedly been made on $^5/_{16}$-in. mild steel which, when subjected to a 90-deg. bend, showed a marked extrusion of the welded material but no sign of fracture. When the welded pieces are cut with a hacksaw, it is very unusual to be able to note any difference in cutting qualities between the unwelded and the welded parts.

"While the automatic machine has not been used on metal less than 0.109 in. thick, it is fair to presume that, with proper adjustments, entirely satisfactory results can be obtained on much thinner work—particularly if the nature of the work is such as to permit of the use of a chill. The best method in welding very light metal seems to be to use a small electrode, a relatively low current, and a high rate of work traverse. In this way welding conditions may be controlled to almost any desired extent, because

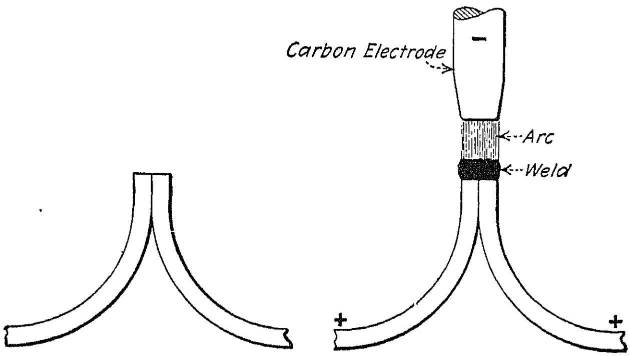


FIG. 189.—How the Metal Edges Are Welded.

the heating action of the arc can be modified, its effect intensely localized, and the edges to be welded subjected to the fusing action for as brief a time as might be found necessary to prevent burning of the metal. These conditions, which seem to be requisite in order to successfully weld very thin material, cannot be met by the manual welder. It is here that the deficiencies incident to the personal equation become most apparent. A very slight variation in arc length or the least hesitancy in moving the arc over the work will almost certainly result in its being burned through. In short, this class of welding calls for a coördination of faculties and a delicacy of manipulation beyond the capabilities of the most skillful manual electric welder. Therefore this work is usually done with the oxy-acetylene flame, wherein fusing conditions are far more easily controlled than is possible in manual metallic electrode arc welding."

SHEET METAL ARC-WELDING MACHINE

The machine shown in Fig. 188 is used by the General Electric Co., Schenectady, N. Y., for arc-welding corrugated steel tank work. The seams are 116 in. long, and the arc

is applied by means of a tapered carbon pencil 6 in. long, $\frac{1}{2}$ in. in diameter at the large end and $\frac{1}{8}$ in. at the arc end. This concentrates heat where wanted. No metal is supplied to the weld, as the arc is employed simply to fuse the upturned edges as shown in Fig. 189. The metal welded is $^1/_{16}$ and $^3/_{32}$ in. thick.

The speed on $^1/_{16}$-in stock is $5^1/_2$ in. per minute with a d.c. current of 45 amp., and 75 volts. On $^3/_{32}$-in. stock the speed is the same but 70 amp. and 75 volts d.c. current is used.

CHAPTER XII

BUTT-WELDING MACHINES AND WORK

Aside from arc-welding machines, which have already been described, electric welding machines may be all included under one head—Resistance Welding Machines. These may be divided into butt-, spot-, seam-, mash- and percussive-welding classes. The first three are sometimes, for manufacturing purposes, used in combinations in the same machine, such as a spot-and-seam machine or a butt-and-spot-welding machine, and so on. This does not mean that these different methods of welding are carried on at the same time, but that a welder can do work on the same machine by simply shifting the work, or a part of the fixture.

In butt-welding, alternating current, single phase, of any commercial frequency such as 220, 440 or 550 volts, 60 cycles, is commonly used. Lower voltages and lower frequencies can be used, but they add to the cost of the machine. The machine can be used on one phase of a two-phase or a three-phase system, but cannot be connected to more than one phase of a three-phase circuit. Direct current is not used because there is no way of reducing the voltage without interposing resistance, which wastes the power. As an example, a d.c. plating dynamo will give approximately 5 volts, which will do for certain kinds of welding, but for lighter work, less current is needed. If resistance is used to reduce the current this resistance is using up power just as if it were doing useful work. The voltage at the weld will run from 1 to 15 volts, depending on the size of the welder and work. To obtain this low voltage, a special transformer inside the machine reduces the power line voltage down to the amount required at the weld. The transformer is placed within the frame of the machine, as shown in Fig. 190. The secondary winding of the transformer is connected to the platens by means of flexible copper leads.

From the platens the welding current travels to the work clamps and through them to the pieces to be welded. As the parts to be welded are brought into contact a switch is thrown in and the current traveling across heats the ends of the work and when the proper welding heat is reached the operator

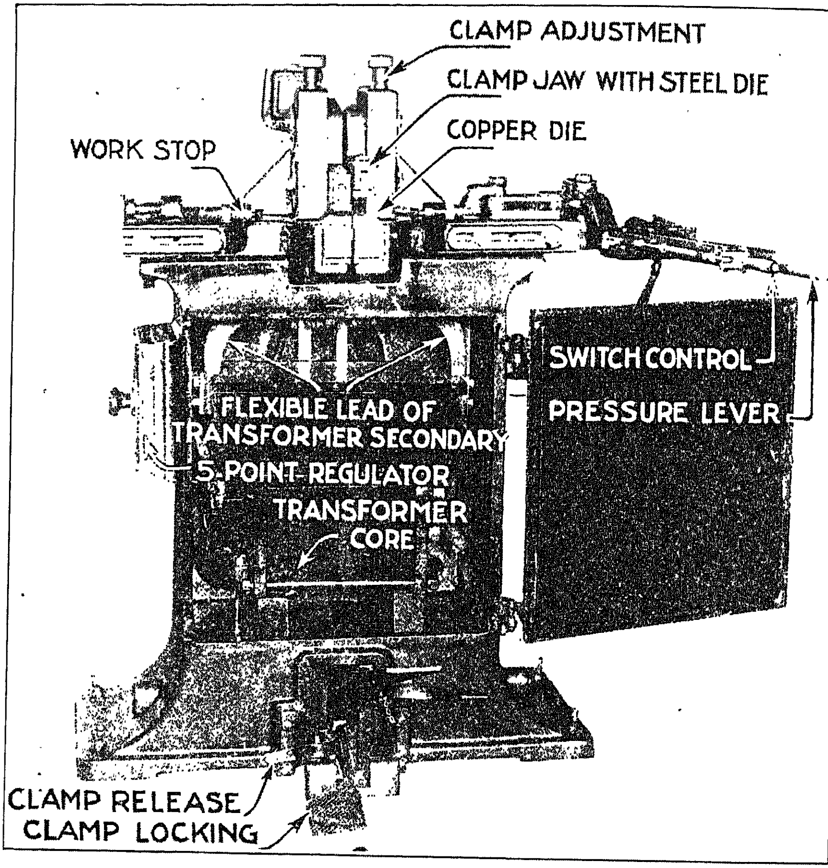


FIG. 190.—Principal Parts of a Butt-Welding Machine.

pushes the two parts together and the weld is completed. Since the current value rises as the potential falls in the secondary circuit, and since the heating effect across the work is directly proportional to the current value it will be easily seen why a transformer is necessary to produce a heavy current by lower-

ing the line potential. Due to the intermittent character of the load, there is no standard rating for welding transformers, and different makers frequently give entirely different ratings for their machines. However, regardless of the rating capacity in kilowatts, there can be very little difference in the actual amount of current consumed unless an especially bad

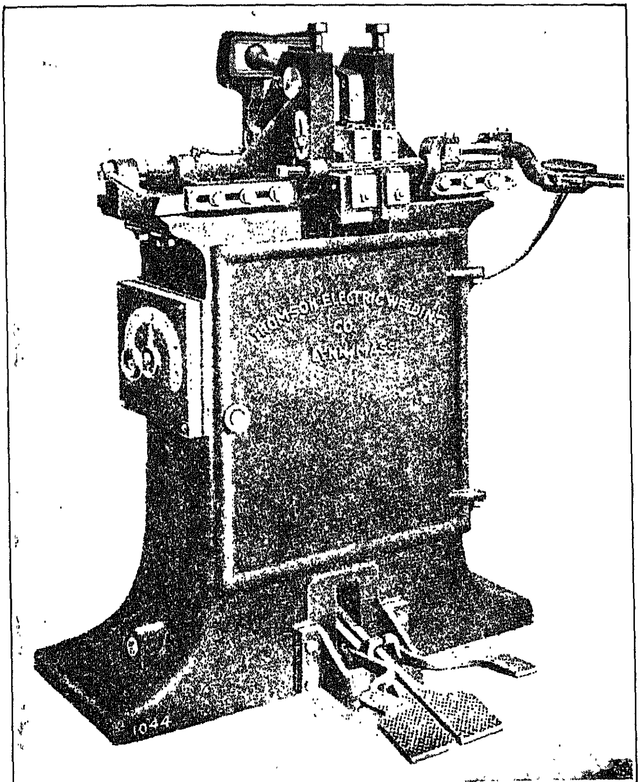


FIG. 191.—Butt-Welding Machine with Work in Jaws.

transformer design is used. To heat a given size stock to welding temperature in a given time requires an approximately invariable amount of current.

The machine just illustrated, is shown at a slightly different angle and with two pieces of rod in the jaws, in Fig. 191. This is the Thomson regular No. 3, butt-welding machine. It

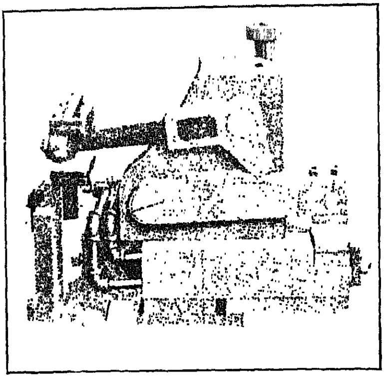


FIG. 192.—Details of Foot-Operated Clamping Mechanism.

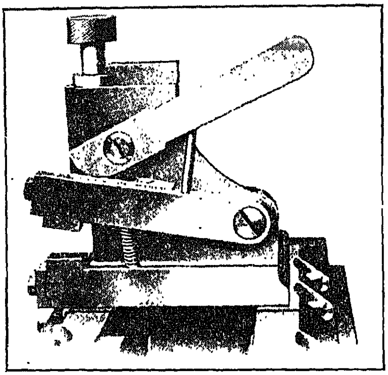


FIG. 193.—A Hand-Operated Clamp.

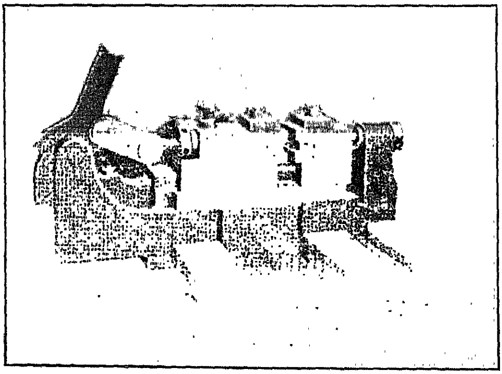


FIG. 194.—Toggle-Lever Clamp for Round Stock.

has a capacity of rod from $\frac{1}{8}$ to $\frac{3}{4}$ in. in diameter or flat stock up to $^1/_4\times 2$ in., in two separate pieces, or rings of $^5/_{16}$-in. stock and not less than 2 in. in diameter. Hoops and bands up to $^1/_{16}\times 1^3/_4$ in. and not less than $9^1/_2$ in. diameter when held below the line of welding, may also be welded. With jaws specially made to hold the work above the line of welding a minimum diameter of $4\frac{1}{2}$ in. is necessary. This machine will produce from 150 to 200 separate pieces, 150 to 300 hoops, or 300 to 400 rings per hour. The lower dies are of hard drawn copper with contact surfaces $1^1/_8\times 2$ in.$\times 2^1/_{16}$ in. thick.

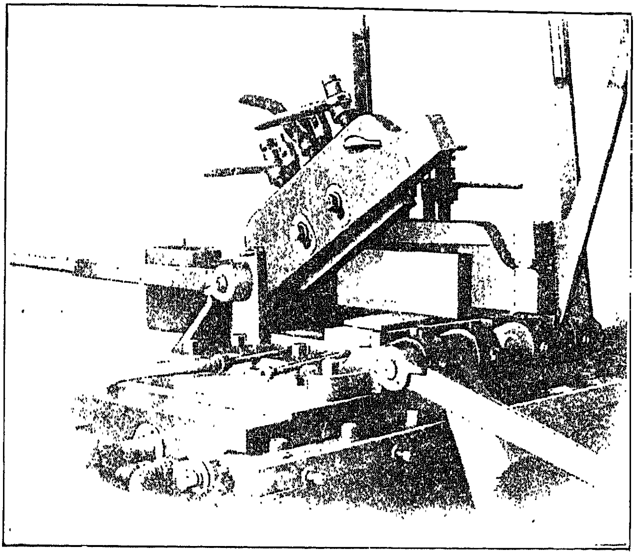


FIG. 195.—Clamping Device for Heavy Flat Stock.

Standard transformer windings are for 220, 440 and 550 volts, 60 cycle current. Current variation for different sizes of stock is effected through a five-point switch shown at the left. Standard ratings are 15 kw. or 22 kva., with 60 per cent power factor. The dies are air cooled but the clamps to which the dies are bolted are water cooled. This type of machine occupies a floor space 40×33 in., and is 53 in. high. The weight is 1,750 lb. A close-up view of the treadle-operated clamping jaw mechanism is given in Fig. 192.

The method of operating the clamping jaws differs accord-

ing to the size of the machine and the work that is to be done. On some of the smaller machines the type of hand-operated clamp shown in Fig. 193 is used. On other machines, intended to handle round stock principally, the toggle lever clamp shown in Fig. 194 is used. For very heavy flat stock, the hand-lever clamping mechanism, shown in Fig. 195, is used. On some of the machines used on small repetition work the clamps and switch are automatically cam-operated as shown in Figs. 196 and 197. The first machine is a bench type used

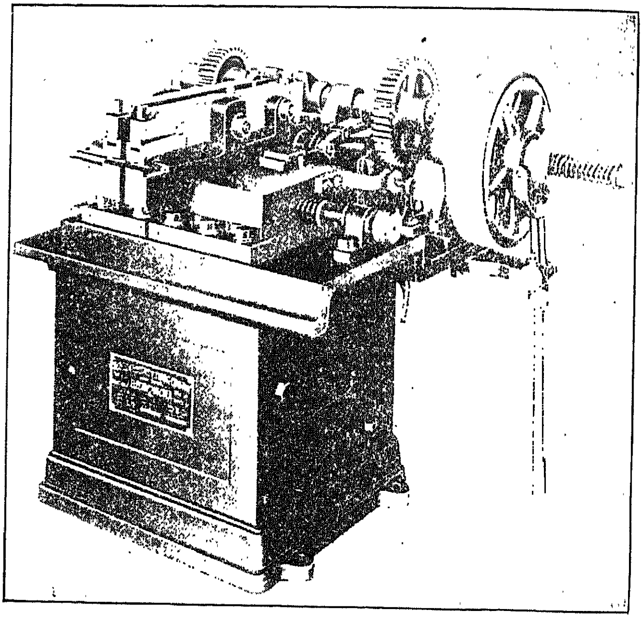


FIG. 196.—A Cam-Operated Machine.

for welding on twist drill shanks, and the second machine is used for welding harness rings. These jobs are, of course, merely examples as the machines are adapted for all sorts of the smaller welding jobs. Spring pressure, toggle-lever or hydraulic pressure are used to give the final "shove-up" according to the machine used or weight of stock being welded.

In welding hard steel wire of over 35 per cent carbon content, it is necessary to anneal the work for a distance of about 1 in. on each side of the weld. This is due to the fact

that the wire on each side is rendered brittle by the cooling effect of the clamping jaws. To accomplish this annealing, all the small Thomson machines used for this work are equipped with a set of V-jaws outside of the clamping jaws, as shown in front in Fig. 198. The wire is laid in these V's with the

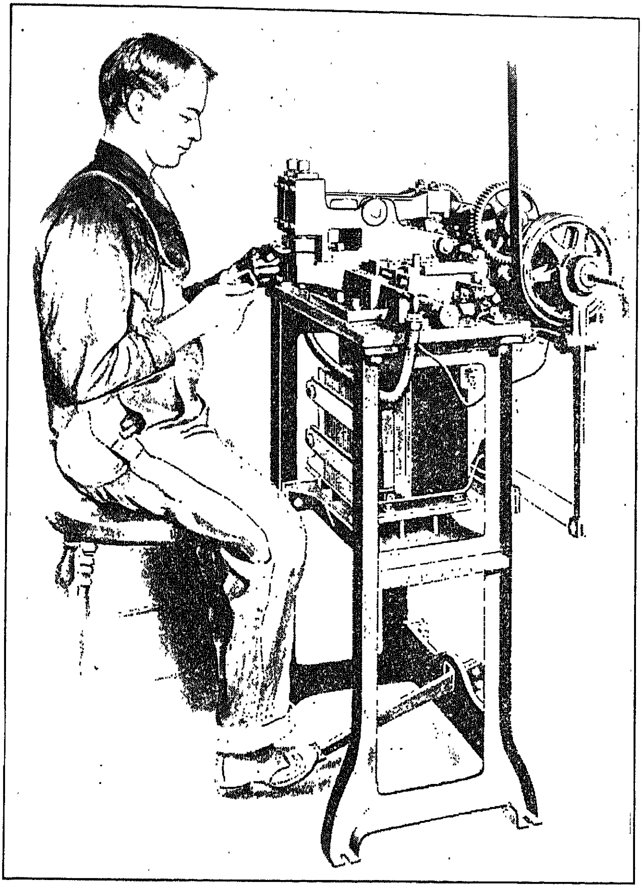


FIG. 197.—Automatic-Operated Machine Welding Harness Rings.

weld half way between and the current is thrown on intermittently by means of a push button until the wire has become heated to the desired color, when it is removed and allowed to cool. The annealing of a small drill is shown in Fig. 199. The process of welding and annealing 12 gage, hard steel wire,

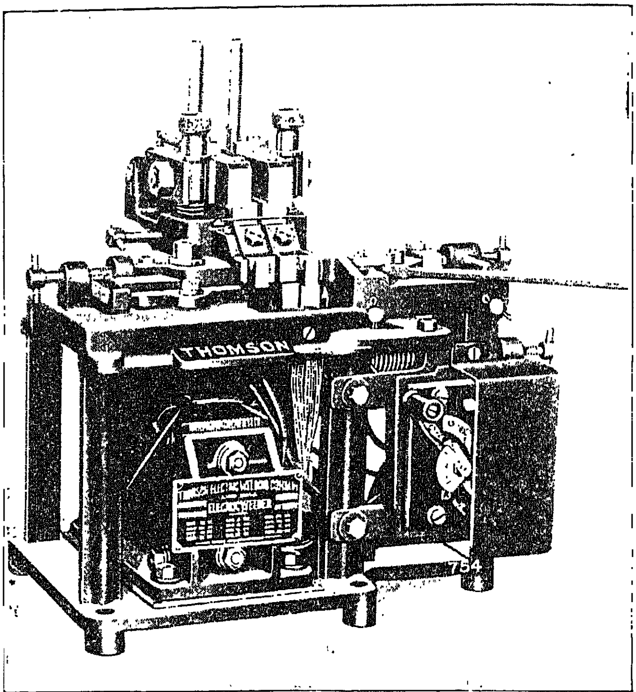


FIG. 198.—Machine Equipped with Annealing Device.

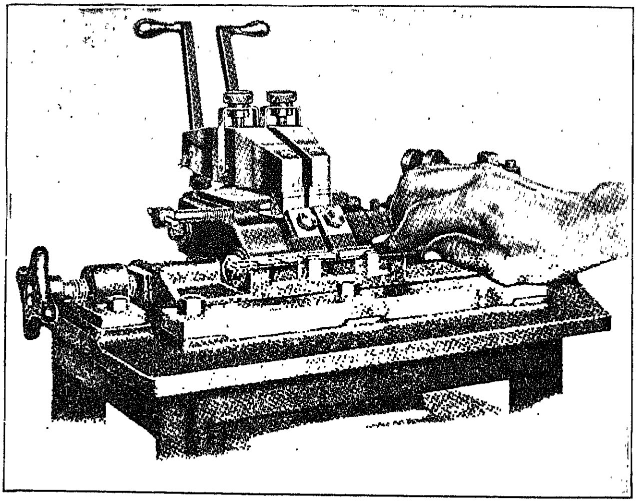


FIG. 199.—Annealing a Small Drill.

requires about 30 sec. when done by an experienced operator. Copper and brass wire are easily welded in these same machines. The machine shown will weld iron and steel wire from No. 21 B. & S. to $\frac{1}{8}$ in. in diameter and flat stock up to No. 25 B. & S.$\times\frac{1}{2}$ in. wide. Production is from 150 to 250 welds per hour, the actual welding time being $1\frac{1}{2}$ sec. on $\frac{1}{8}$-in. steel wire. The clamps are spring-pressure, with adjustable tension released by hand lever. The standard windings are furnished for 110, 220, 440 and 550 volts, 60 cycles. Five variations are made possible by the switch. The ratings are $1\frac{1}{2}$ kw. or 3 kva., with 60 per cent power factor. The weight is 120 pounds.

For use in wire mills where it is desired to weld a new reel of wire to the end of a run-out reel on the twisting or braiding machines, it has been found convenient to mount the machine on a truck or small bench on large casters. This enables one to move the welder from one winding machine to another very easily, to splice on new reels of small wire, the electrical connection to the welder being made by flexible cord, which is plugged into taps arranged at convenient points near each winding machine. It is also desirable to mount on this same bench a small vise in which to grip the wire to file off the burr resulting from the push-up of the metal in the weld. The average time required to weld, anneal and file up a 16-gage steel wire with this bench arrangement is only about one minute. The only preparation necessary for welding wire is that the stock be clean and the ends be filed fairly square so that they will not push by one another when the pressure is applied.

In connection with welding wires and rods up to $\frac{7}{8}$ in. in diameter, Table XX will be found very handy. For sizes from $\frac{1}{4}$ to $2\frac{1}{4}$ in. the reader is referred to Table XXVI.

Examples of Butt-Welding Jobs.—while, as a rule, it is only necessary to have clean and fairly square ends for butt-welding in some cases where small welding is to be done it has been found best to bevel or V the abutting ends. This is more apt to be the case with non-ferrous metals, however, than with iron or steel. A notable example in the larger work is in the scarfing of the ends of boiler tubes when butt-welding is done. This phase of the question has apparently not been given the attention it deserves, and some cases where welding

TABLE XX.—APPROXIMATE CURRENT CONSUMPTION FOR WELDING UP TO $\frac{7}{8}$ IN. ROD

Dia. of rod in inches		Wire gauge		Dia. of rod in millimeters	Area of section in square in.	Current consumption per 1000 welds in K. W. H.	Cost per 1000 welds at 1 c. per K. W. H.*	Dia. of rod in inches		Wire gauge		Dia. of rod in millimeters	Area of section in square in.	Current consumption per 1000 welds in K. W. H.	Cost per 1000 welds at 1 c. per K. W. H.*
Dec.	Frac.	B. & S.	Birm.					Dec.	Frac.	B. & S.	Birm.				
.03196		20			.00079	2	$0.02	.2043		4			.03277	7	$0.07
.035			20		.00095	2	.02	.2362				6	.0438	8	.08
.0394				1	.00121	2	.02	.238			4		.0448	9	.09
.0403		18			.00127	2	.02	.25	1/4				.04909	10	.10
.049			18		.00169	2	.02	.2576		2			.0521	10	.10
.0508		16			.00205	2.5	.025	.2755				7	.0596	11	.11
.0625	1/16				.00307	2.5	.025	.284			2		.0633	11	.11
.0641		14			.00326	2.5	.025	.3125	5/16				.0767	12	.12
.065			16		.00332	2.5	.025	.3149				8	.0779	12	.12
.0787				2	.00486	2.5	.025	.3249		0			.0829	12	.12
.0808		12			.00513	2.5	.025	.34			0		.0908	13	.13
.083			14		.00678	2.5	.025	.3543				9	.0987	14	.14
.1019		10			.00817	3	.03	.375	3/8				.11045	15	.15
.109			12		.00934	3	.03	.3937				10	.1217	16	.16
.1181				3	.01025	3.5	.035	.4724				12	.1753	19	.19
.125	1/8				.01227	4	.04	.5	1/2				.19635	20	.20
.128		8			.01287	4	.04	.5612				14	.2472	26	.26
.134			10		.01411	4.5	.045	.625	5/8				.3068	30	.30
.1575				4	.01948	5	.05	.6299				16	.3115	34	.34
.162		6			.02061	5.5	.055	.7087				18	.3946	45	.45
.165			8		.02139	5.5	.055	.75	3/4				.44179	52	.52
.1875	3/16				.02761	6	.06	.7874				20	.487	60	.60
.1968			6	5	.03043	6.5	.065	.8661				22	.585	80	.80
.203					.0327	7	.07	.875	7/8				.60132	85	.85

*Multiply these values by the rate you are paying per K. W. Hour for current, to determine what the cost per 1000 welds for any size would be at your plant.

has been declared a failure in manufacturing may be laid to the fact that the parts to be welded were not scarfed and consequently would not stand the required tests after being welded. As a general rule, a properly executed butt-weld should, when reduced to the size of the original section, have practically the same strength.

Although copper and brass rod and strip can be welded

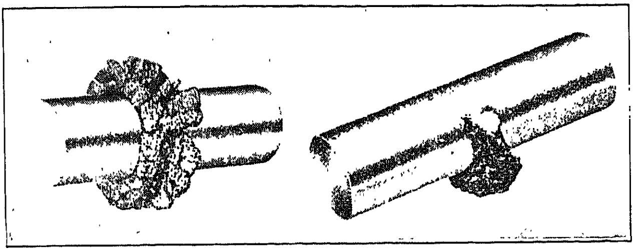


FIG. 200.—Typical Copper Welds.

with perfect success, owing to the nature of the metal it requires a specially constructed machine to secure the best results. Since copper has a very low specific resistance as compared to iron or steel, it requires much more current to melt it on a given size rod. A longer time is required also to heat a given size of rod as compared to steel, but when

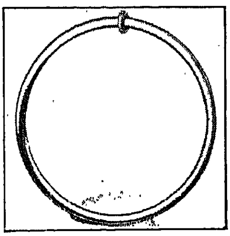


FIG. 201.—Welded Aluminum Ring.

the plastic stage is reached the metal flows so rapidly that it must be pushed up with tremendous speed or the molten copper will flow out between the abutting ends. To effect this rapid push-up of stock the platen on which the movable right-hand clamp is mounted must move very freely indeed, necessitating roller bearings on the larger sizes of machines. The

pressure spring on the smaller machines must also be capable of maintaining its tension through a longer distance than on

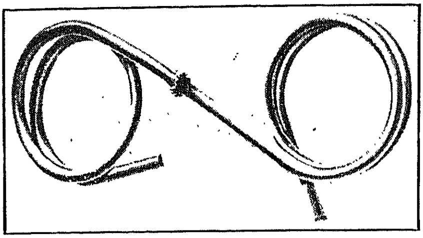


FIG. 202.—A Steel Wire Weld.

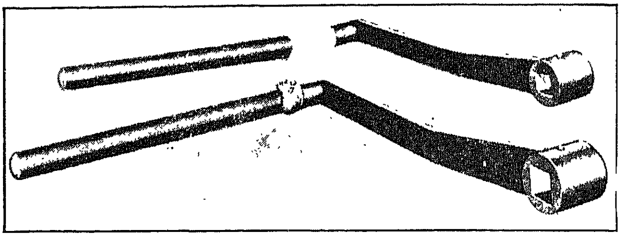


FIG. 203.—Welded Hoisting Drum Crank Forging.

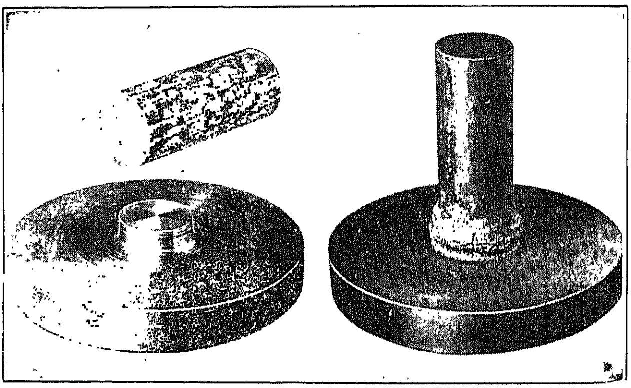


FIG. 204.—Large Welded Pinion Blank.

a machine for iron and steel, since more metal is pushed up on a given size of copper rod than would be on steel or iron.

The properties of brass and also aluminum are practically

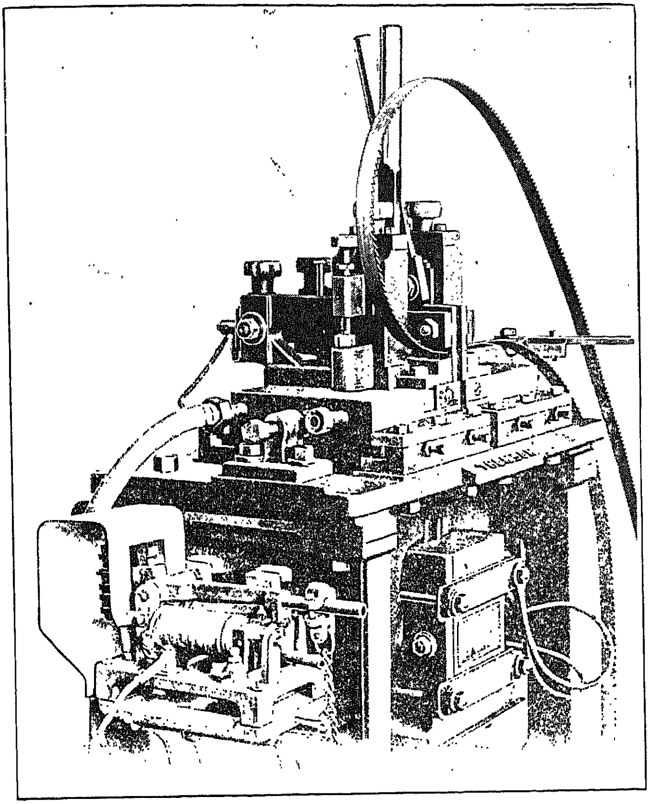


FIG. 205.—Welding a Band Saw.

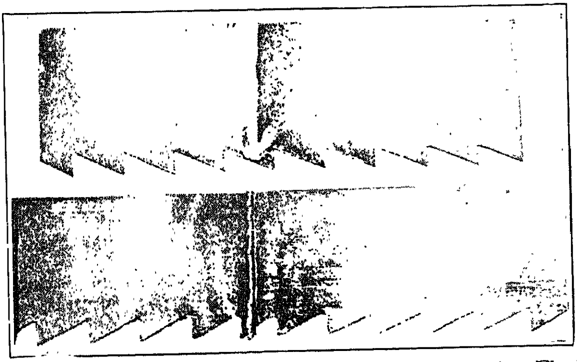


FIG. 206.—Bandsaw Weld before and after Removing Flash.

the same as those of copper and therefore this special type of machine is just as well adapted for these metals.

Typical copper welds are shown in Fig. 200. The one at the left shows it just as it came from the machine, and the one at the right with the flash partly removed. Fig. 201 shows an aluminum ring immediately after welding. A steel wire weld is shown in Fig. 202, and a welded hoisting drum crank in Fig. 203. This last illustration shows how some drop forgings may be simplified and the cost of dies and production lessened. A large pinion gear blank is shown in Fig. 204. Made in this way, a large amount of time and metal is saved. The way to weld pieces of large and small cross section is described in the article on tool welding.

Band saws may be butt-welded as shown in Fig. 205. The way a band saw looks after welding and after the flash is removed is shown in Fig. 206.

T-WELDING

T-welding, which is a special form of butt-welding, is, as its name implies, the process of making a weld in the shape of the letter "T". Where it is desired to weld a piece of iron to the middle of another bar of equal size or larger, it becomes necessary to heat the top bar of the "T" to a bright red; then bring the lower bar to the preheated one and again turn on the current, when a weld can quickly be made. The reason for doing this is as follows: The pieces are of unequal area in cross-section at the junction of the two pieces. As it takes longer to heat the upper part, the end of the lower part of the "T" would burn before the upper piece would reach the welding temperature. Preheating will equalize and overcome this difficulty. Special machines known as "T" welders are built for this class of work to facilitate the preheating, when the highest possible production on this form of weld is desired.

Automobile Rim Work.—One of the largest applications of butt-welding today is to be found in the automobile-rim industry. The special form of clamp shown in Fig. 195 was especially designed to handle rims of all kinds and sizes. It is not adaptable for any type of work other than flat stock,

as the amount of jaw-opening is much smaller than the diameter of equivalent section of round stock.

No backing-up stops of any kind are built for these machines with rim-clamps, as stops are unnecessary for this class of work. In order to secure sufficient gripping effect of the stock to prevent it slipping in the clamp-jaws, the upper dies are made of self-hardening steel with the gripping surface corrugated. The lower dies, which carry all the current to the work, are made of copper with Tobin-bronze shoes on which the work rests, so as to give good conductivity and yet present a hard wearing surface to the steel rim. These lower dies must not only bear the gripping effort exerted by the steel dies above, but also the weight of the rim, which, in large sizes, amounts to considerable.

The method employed in welding automobile rims is the "flash-weld" principle, wherein the current is first turned on with the edges to be welded pulled apart. The pressure is then applied gently to bring the abutting ends slowly together. As uneven projections come into contact across from opposite edges they are burned or "flashed" off, which is evidenced by flying particles of burning iron. The pressure is gradually increased, bringing more of the length of the opposite edges into contact and when the "flash" throws out for the full width of the rim which indicates the abutting ends are touching all the way across, the final pressure is quickly applied as the current is turned off, thereby completing the weld. It has been found that experienced operators on this kind of work do not look at the weld itself but govern their actions by the appearance of the amount of flash or sparks thrown out. When this assumes the shape of a complete fan they know it is the right moment to cut off the current and apply the final pressure.

The burr or fin thrown up in this type of weld is very short and very brittle, making its removal much easier than would be the case with the heavy burr resulting from a slow butt-weld. It is the common practice in rim plants to remove the burr while it is still hot and with a pneumatic chisel or a sprue cutter. The slight amount of burr then remaining is ground off with a coarse abrasive wheel and the rim is ready for the forming process. In most rim plants the operations

of rolling, welding, chiseling burr, grinding burr, forming, shaping, etc., fit in so closely to one another that a rim is practically kept moving continuously from the time the flat stock is put into the rolls until a finished rim emerges. The welding operation itself on a rim blank for $30 \times 3\frac{1}{2}$ tire size, for instance, has an average production rate of 60 rims per hour, some concerns doing even better than this. On large

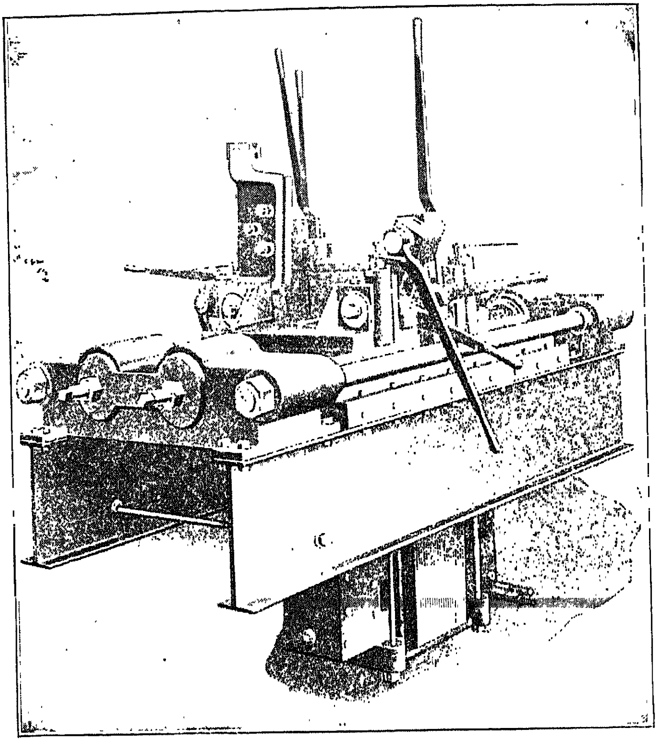


FIG. 207.—Truck Rim Welding Machine.

truck rims for solid tires, having a section of $16 \times \frac{3}{8}$ in. thick, a production of 10 rims per hour is considered very good, although there are concerns doing even better than this on such heavy work.

The machine shown in Fig. 207 was specially designed for handling heavy truck rims only. The lower jaws on this welder are placed very low in order that the machine can

be set in a comparatively shallow pit to bring the line of weld on a level with the floor. This makes it possible, with proper tracking arrangements, to roll heavy rims right onto the lower dies without any lifting, the rim being rolled out again after welding. The double oil-transformers used in this welder hang below the base line, which necessitates a small pit directly under the center of machine. Owing to this and also the weight to be supported, a concrete foundation only should be employed.

This machine has a capacity for stock $\frac{3}{4}\times8$ to $\frac{3}{8}\times16$ in., or a maximum thickness of 1 in. with a cross-sectional area of not over 7 sq. in. Rims with a minimum diameter of 30 in. can be welded. The pressure is effected by twin hydraulic

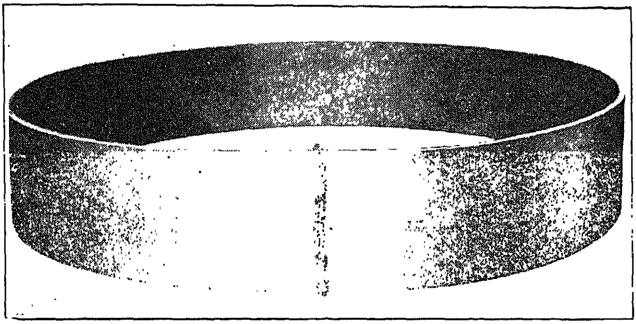


FIG. 208.—A Heavy Welded Rim.

cylinders operated from an external accumulator giving a maximum pressure of 24 to 37 tons on the work. The voltage windings are of the same capacity as for other machines. The transformer is of the oil cooled type, and the ratings are 160 kw. or 266 kva., with 60 per cent power factor. Primary windings of transformers are submerged in cooling oil contained in casings. Platens on which the clamps are mounted and the bodies of the lower jaws to which the contact shoes are bolted, are water cooled. This machine is 66×101 in. and 66 in. high. The net weight is 14,000 pounds.

A heavy rim after welding is shown in Fig. 208.

Welding Pipe.—In order to weld pipe and tubing in the form of coils for condenser systems cooling tubes, heating coils, etc., as shown in Fig. 209, it was found necessary to

employ a special form of clamp wherein the jaws could be set up high to give clearance above the pressure-device. The thickness of the die and die-block to which it is bolted also had to be reduced to a minimum so as to insert the jaws between coils, since the pipe is coiled through each length and then another length is welded on, which in turn is coiled, and so on. In order to secure the best gripping effect with a comparatively light die, it is necessary to make this form of die considerably longer than those used in the other types

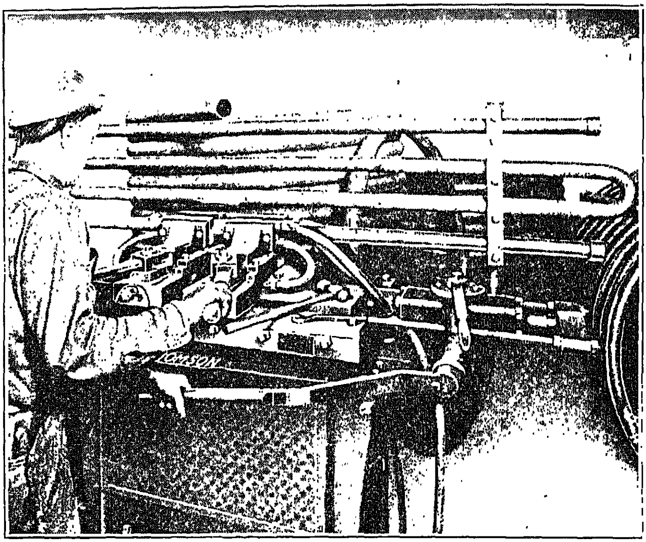


FIG. 209.—Welding Pipe Coils.

of horizontal-acting clamps. Moreover, since there is not enough space in the narrow block to which the die is bolted to permit water circulation, the die itself must be water-cooled to prevent softening of the copper from continued contact with the hot pipe just in back of the weld.

This type of clamp, Fig. 210, is designed for welding of pipe and tubing only, which requires a much lighter pressure to push up than solid stock of the same cross-sectional area, and since the line of weld is considerably above the line of pressure, the slides will be quickly worn on the movable platen if heavy pressure is used continually. For this reason the

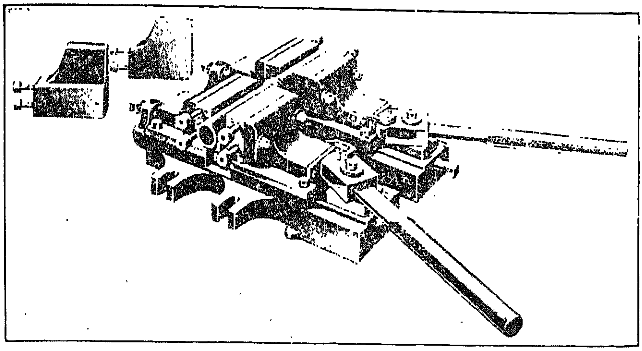


FIG. 210.—Clamp Used for Pipe Welding.

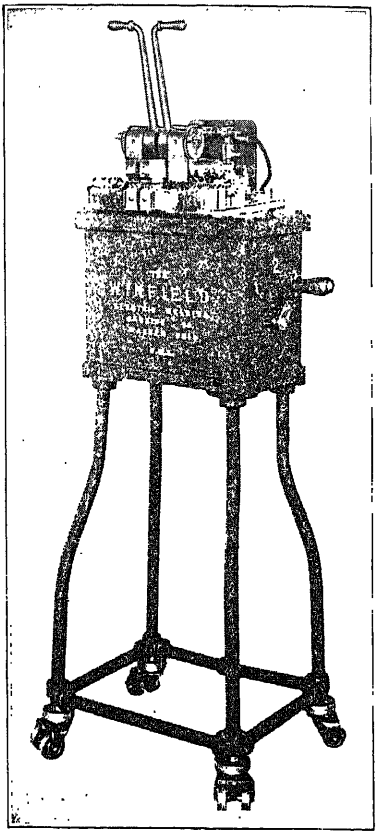


FIG. 211.—Winfield Portable Butt-Welding Machine.

TABLE XXI.—APPROXIMATE CURRENT CONSUMPTION FOR WELDING PIPE UP TO 4½ IN.

Ordinary Sizes

Diameters: Nominal Internal	Diameters: Actual Internal	Diameters: Actual External	Pipe Wall Thickness
⅛	.27	.405	.068
¼	.364	.54	.088
⅜	.494	.675	.091
½	.623	.84	.109
¾	.824	1.05	.113
1	1.048	1.315	.134
1¼	1.38	1.66	.14
1½	1.611	1.9	.145
2	2.067	2.375	.154
2½	2.468	2.875	.204
3	3.067	3.5	.217
3½	3.548	4.	.226
4	4.026	4.5	.237
4½	4.508	5.	.246

Extra Heavy

Diameters: Nominal Internal	Diameters: Actual Internal	Diameters: Actual External	Pipe Wall Thickness
⅛	.205	.405	1
¼	.294	.54	.123
⅜	.421	.675	.127
½	.542	.84	.149
¾	.736	1.05	.157
1	.951	1.315	.182
1¼	1.272	1.66	.194
1½	1.494	1.9	.203
2	1.933	2.375	.921
2½	2.315	2.875	.28
3	2.892	3.5	
3½	3.358	4	

Double Extra Heavy

Diameters: Nominal Internal	Diameters: Actual Internal	Diameters: Actual External	Pipe Wall Thickness
½	.244	.84	.298
¾	.432	1.05	.314
1	.587	1.315	.364
1¼	.885	1.66	.388
1½	1.088	1.9	.406
2	1.491	2.375	.442
2½	1.756	2.875	.56

Miscellaneous Data

Square Inch Cross section	Weight in Lbs. per Foot	Current Consumption per 1000 Welds	Cost per 1000 Welds at 1 c. per K.W.H.*
.0717	.241	12	$0.12
.086	.29	13	.13
.1249	.42	16	.16
.161	.54	18	.18
.1663	.559	19	.19
.219	.74	21	.21
.2492	.837	26	.26
.323	1.09	35	.35
.3327	1.115	37	.37
.414	1.39	50	.50
.4954	1.668	60	.60
.507	1.7	70	.70
.648	2.17	90	.90
.668	2.244	100	1.00
.727	2.44	110	1.10
.797	2.678	130	1.30
.893	3	160	1.60
1.074	3.609	210	2.10
1.082	3.63	220	2.20
1.087	3.65	230	2.30
1.495	5.02	340	3.40
1.549	5.2	360	3.60
1.708	5.739	410	4.10
1.905	6.4	460	4.60
2.243	7.536	570	5.70
2.283	7.67	590	5.90
2.679	9.001	740	7.40
2.686	9.02	760	7.60
3.052	10.25	850	8.50
3.174	10.665	940	9.40
3.674	12.35	1150	11.50
3.71	12.47	1190	11.90
4.073	13.68	1300	13.00

* Multiply these values by the rate you are paying per K.W. hour for current, to determine what the cost per 1000 welds for any size would be at your plant.

welding of any solid stock with this class of machine is not advisable.

The machine shown will weld iron and steel pipe from $\frac{3}{4}$ to 2 in. in diameter, ordinary pipe sizes and $1\frac{1}{2}$ in. extra heavy pipe, or double heavy 1 in. in diameter. Standard steel tubing

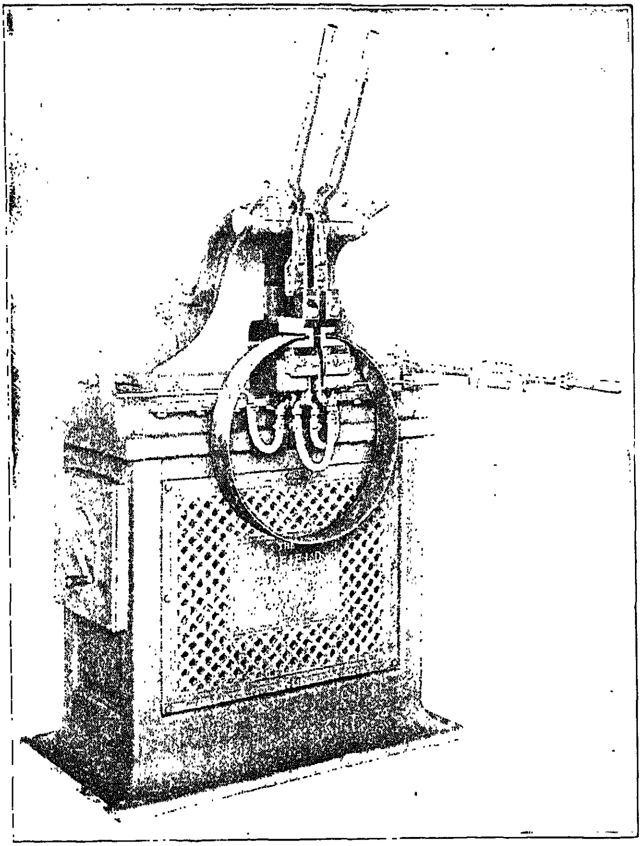


FIG. 212.—A General Purpose Butt-Welding Machine.

from 1 to $2\frac{1}{4}$ in. diameter may be welded. Pressure is supplied by a hydraulic oil jack exerting a maximum of 5 tons. The standard ratings are 30 kw. or 50 kva., with power factor of 60 per cent. The machine will weigh about 2,500 pounds.

For welding pipe, Table XXI will be found useful for

reference purposes. This table was compiled by the Thomson Electric Welding Co., with special reference to their machines.

Winfield Butt-Welding Machines.—The Winfield Electric Welding Machine Co., Winfield, Ohio, makes a complete line of butt-welding machines but only a few representative of their line, will be shown. A very convenient portable or bench type is shown in Fig. 211. This is especially useful for light manufacturing work. It has a capacity of 18 to 6 gage wire. It is equipped with a 1 kw. transformer, hand clamping levers and a 3-step self-contained regulator for controlling the current. It occupies a floor space of $13\frac{1}{2}\times 16$ in., is 35 in. high from floor to center of welding dies, and weighs about 130 lb. complete.

The machine shown in Fig. 212 is for general all-round shop work. It has a capacity of from $\frac{1}{4}$ to 1 in. round, or $\frac{3}{8}\times 2$ in. flat stock. It has a 25-kw. transformer, water-cooled welding jaws, enclosed non-automatic switch on upsetting lever, stop for regulating amount of take-up on each weld, ten-step self-contained regulator for controlling the current, occupies a floor space of 44×25 in., is 42 in. high to center of jaws and weighs about 1,800 lb. The jaws overhang as shown, for welding hoops, rings, rims, etc.

The machine shown in Fig. 213 is for toolroom work and was especially designed for handling large cross-sections. It will weld up to $2\frac{1}{2}$ in. round. All clamping and upsetting operations are accomplished by means of air or hydraulic pressure. The clamping cylinders are operated independently of each other by means of separate valves, which enable the operator to clamp each piece before the current is turned on. The small air cylinder on the right-hand end of the machine keeps the work in close contact during the heating operation. The final pressure is applied by the hydraulic ram after the proper welding heat has been attained. The table at the left is equipped with adjustments for moving it up or down, back and forth, tilting or twisting. This feature is especially valuable in experimental work and often saves buying a special machine for unusual manufacturing jobs. The terminals are cooled by a stream of water which flows from one to the other. The dies are held in place by slotted clamps which permit easy removal. Work stops and stops to regulate the amount of

upset are provided. The movable table is fitted with roller bearings to insure easy operation. The transformer is a Winfield 125 kw. The machine has a ten-step current regulator, and the current for welding is controlled by a Cutler-Hammer magnetic switch which in turn is operated by means of a small auxiliary switch placed on the valve lever controlling the hydraulic ram. The floor space occupied is 60×90 in., and the approximate weight, ready for shipment, is 8,000 lb.

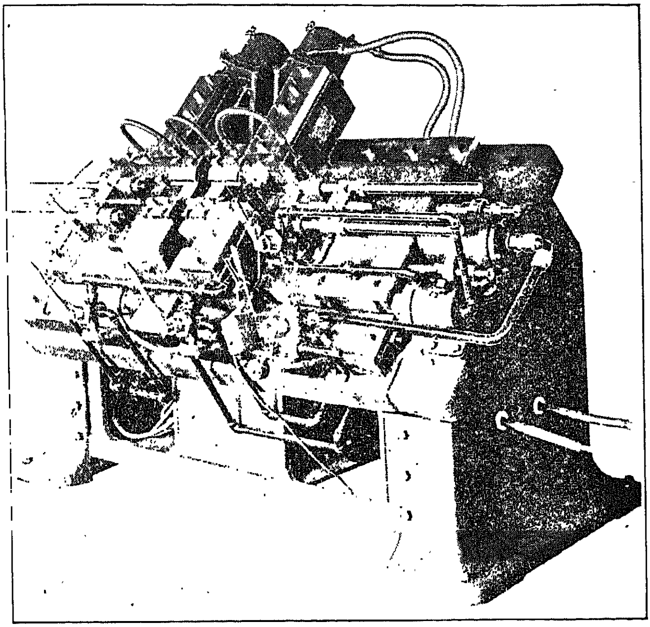


FIG. 213.—Winfield Toolroom Machine.

Table XXII compiled by this concern contains some useful data not given in the other tables.

Federal Butt-Welding Machines.—The machines built by the Federal Machine and Welder Co., Warren, Ohio, do not differ in the principles of operation from the machines already described. The form of the one shown in Fig. 214, however, differs considerably from any shown. The tables, or platens, are flat and are T-slotted so that various fixtures may be easily bolted in place. The maximum capacity for continuous service, is $2\frac{1}{4}$ in. round or other shape of equal section. Flats up to

$\frac{3}{8} \times 10$ in. may be welded. The platens are of gunmetal and the T-slots will take $\frac{3}{4}$-in. bolts. These platens are recessed and water-cooled. Pressure is applied by means of an hydraulic jack, shown at the right. The switch is remote control magnetically operated. The main switch is controlled by a small shunt switch which is worked either by hand or foot, as desired. The transformer is 100 kva. It has an eight-step regulating coil. Floor space occupied is 38×88 in., height 50 in., weight 5,600 lb. This machine is intended to weld auto-rims, heavy forgings, steel frames, shafting, high-speed steel and work

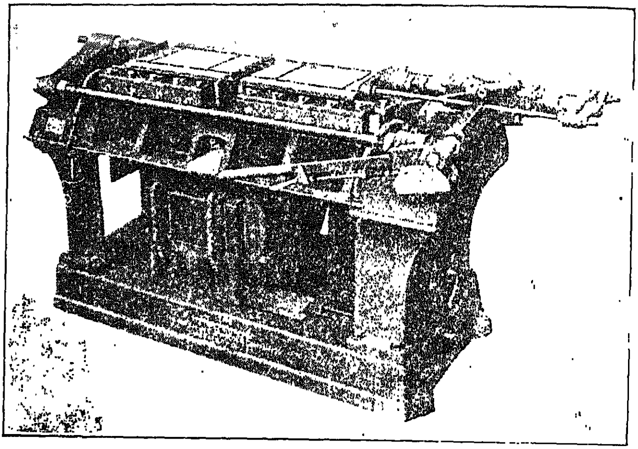


FIG. 214.—Federal Heavy-Duty Butt-Welding Machine.

requiring accurate alignment and rapid production in quantities.

A set consisting of a tube welder and roller is shown in Fig. 215. This will weld tubes from $1\frac{1}{4}$ to 3 in. It will also weld flat, round or square stock of equivalent cross section. The dies are water-cooled, and the work is clamped in position by air cylinders operating on a line pressure of 80 to 100 lb. The switch is on the main operating lever, so that the heat is at all times under the control of the operator. The transformer is 65 kw. air cooled. Eight current steps are obtained. The machine occupies a floor space of 30×51 in., is 42 in. high, and weighs 2,100 lb. By using the set, a tube may be welded and immediately transferred to the rolling machine and the

TABLE XXII.—COST OF $\frac{1}{4}$ TO 2 IN. WELDS PER THOUSAND

Diameter of Stock	Area in Square Inches	K. W. Required	Horse Power	Time in Sec. Per Weld	Cost Per 1000 Welds at 1 c. Per K.W. Hour	Average No. of Welds Per Hour	Labor Cost Per 1000 at 30c. Per Hour
$^1/_4$ Inch	.05	2	3	3	.02	400	.75
$^5/_{16}$ "	.08	3	4	4.5	.05	375	.80
$^3/_8$ "	.11	4	5	6	.07	350	.85
$^7/_{16}$ "	.15	5	7	6.5	.10	300	1.00
$^1/_2$ "	.20	6	8	7	.12	250	1.20
$^9/_{16}$ "	.25	7	9	7.5	.15	200	1.50
$^5/_8$ "	.31	8	11	8	.18	150	2.00
$^{11}/_{16}$ "	.37	9	12	9	.23	130	2.30
$^3/_4$ "	.44	10	13	10	.28	100	3.00
$^{13}/_{16}$ "	.52	10.5	14	12	.35	95	3.20
$^7/_8$ "	.60	11	15	15	.46	90	3.30
$^{15}/_{16}$ "	.69	11.5	15.5	17	.55	85	3.50
1 "	.79	12	16	18	.60	80	3.70
$1^1/_8$ "	.99	16	21	20	.89	75	4.00
$1^1/_4$ "	1.23	19	25	25	1.32	70	4.30
$1^3/_8$ "	1.48	25	33	30	2.08	65	4.60
$1^1/_2$ "	1.77	31	41	35	3.00	60	5.00
$1^5/_8$ "	2.07	38	51	37	3.90	55	5.50
$1^3/_4$ "	2.41	45	60	40	5.00	48	6.20
$1^7/_8$ "	2.76	53	71	43	6.34	40	7.50
2 "	3.14	60	80	45	7.50	30	10.00

flash rolled out. The time consumed in rolling down the flash on a $2\frac{1}{4}$-in. tube is given as approximately 20 seconds.

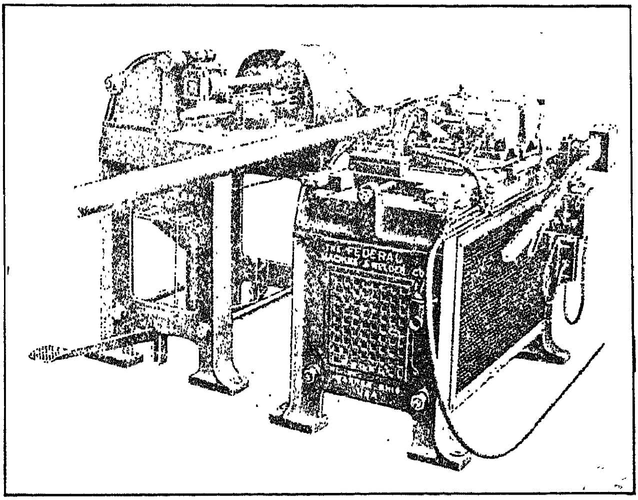


FIG. 215.—A Tube-Welding Set.

Welding Rotor Bars to End Rings.—In the *General Electric Review* for December, 1918, E. F. Collins and W. Jacob describe

the welding of rotor bars to the end rings used in squirrel-cage induction motors, employing the machine shown in Fig. 216. This machine has a double set of welding jaws, the front set being used to butt-weld end rings to make them seamless, while the rear set is used to weld the rotor bars to the end rings. As shown, the machine is welding rotor-bars to the end-rings. The description of the work as carried out in the General Electric shops is as follows:

"The projecting rotor bars surround a toothed end ring,

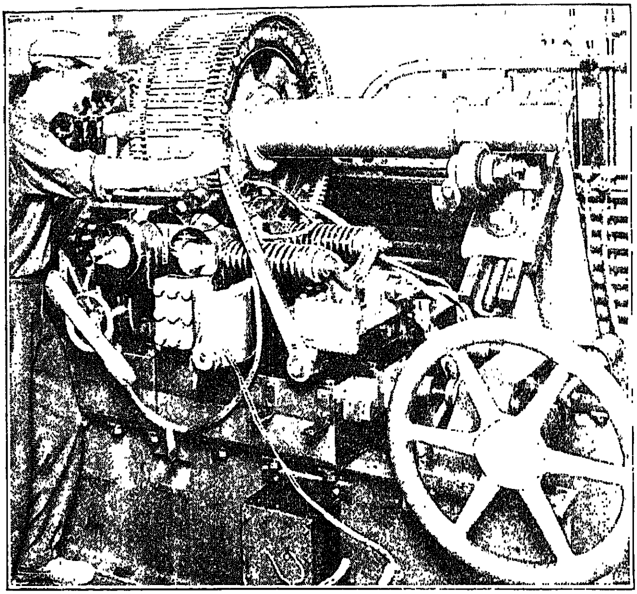


FIG. 216—General Electric Machine for Rotor Work.

which is of slightly smaller diameter than the rotor. A small block of copper is placed so that it covers the copper end surfaces of a rotor bar and the corresponding tooth on the end ring, after which it is butt-welded into place.

The projecting rotor bars are shown at *A* in Fig. 217 and the toothed end ring just inside the circle of rotor bars is shown at *B*. Finished welds as at *C* show blocks in place. The actual operation is as follows: A rotor bar is tightly clamped to the corresponding tooth of the end-ring between the jaws *D* and *E*. The copper-block end-connection is placed

so that it covers the combined area of tooth and bar ends. The movable jaw F holds the end connection in place, and heavy pressure is then applied through compression springs. The welding current, furnished by a special transformer having a one-turn secondary, passes from jaw F through the surfaces and out through jaw E. This heavy current at low voltage causes intense heating due to the comparatively high resistance

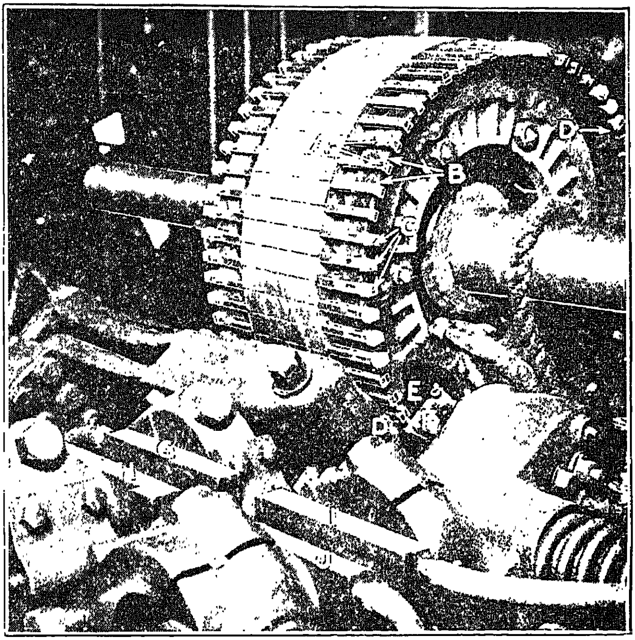


FIG. 217.—Details of the Welding Mechanism and Work.

at the surface junction, and raises the temperature of the copper to welding heat, at which point the metal is plastic.

At this stage spring pressure forces the jaw F toward the rotor and squeezes out any oxide which may have formed between the welding surfaces. A small stream of water, playing upon the hot area, forms an atmosphere of super-heated steam which prevents the formation of oxide and also guards against excessive heating of the copper. No flux is used in the operation as the mechanical squeezing-out of the oxide

is sufficient to form a homogeneous connection between the two surfaces.

As the welding jaws approach one another when the metal becomes plastic, an electrical connection is automatically made which operates a solenoid-controlled switch that opens the primary transformer circuit. Thus the current is interrupted as soon as the surfaces have knitted together. The contacts of this automatic switch are placed one on each movable jaw, and are so adjusted that they are separated by the distance necessary for the jaws to approach one another in forming

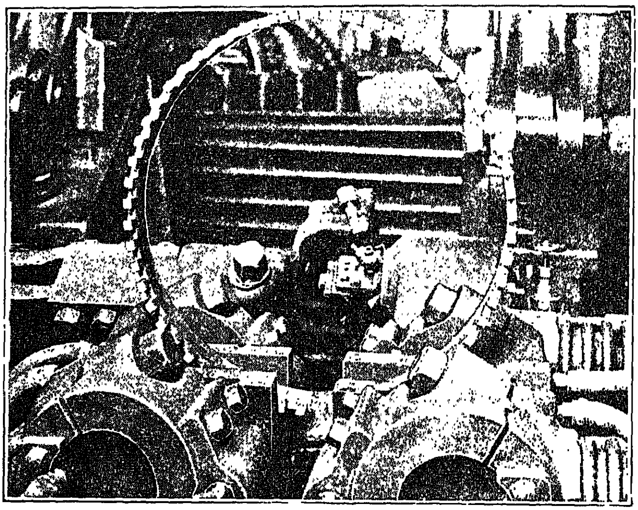


FIG. 218.—Butt-Welding the End Rings.

the weld and in forcing out the oxide. In this way, the end connection is butt-welded to the rotor bar and the end ring, forming a junction of great mechanical strength and low resistance.

Another example of non-ferrous butt welding is the making of seamless end rings, which operation is performed in the same machine. The operation is shown in detail in Fig. 218, which shows a finished end ring in place. One end of the ring is placed in the vise-jaws *G* and *H*, and the other is held in the opposite jaws *I* and *J*. As the jaws approach pressure is applied by means of the springs. In all other respects the operation is similar to that of welding the end connections.

Rotors up to 14 ft. in diameter are welded and Fig. 219 shows the rotor for a 1,400-hp. motor being welded.

The work is done rapidly; for example, end connections with a welding surface of about 0.6 by 0.4 in. are welded at the rate of about 90 an hour.

Welding Brass.—Brass rotor bars and end rings are also butt-welded in a similar manner, but the operation is slower. Brass, being an alloy, has a lower melting point than copper,

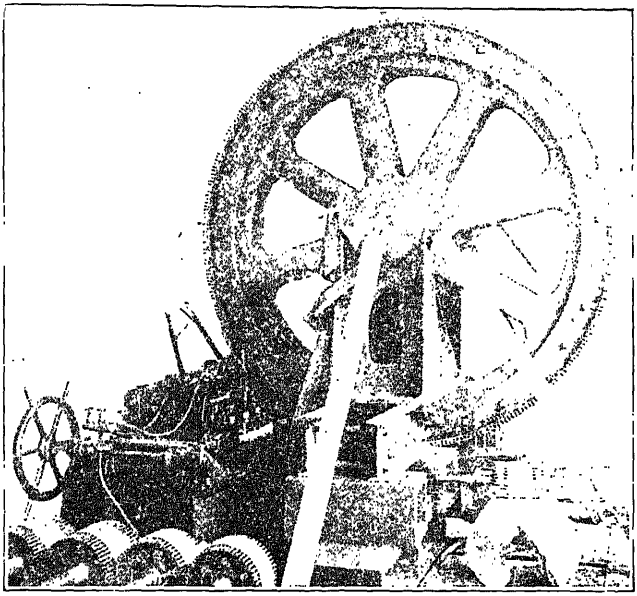


FIG. 219.—Welding End Ring and Rotor Bars for 1400-H.P. Motor.

and less pressure is necessary to effect a weld. The pressure is determined by the thickness of the piece to be welded, and should be just enough to form a small "flash" at the point of union. Excessive pressure will cause the molten metal to spurt out from the point of weld. In one fundamental particular the butt-welding of brass differs from that of copper, the pressure on brass must not be released after the stoppage of current until the metal has hardened sufficiently so that it will not crack on cooling. This delay retards the rate of welding to the extent that about 60 brass end connections,

of the size previously mentioned, require the same time as 90 of copper.

Butt-welding has been the means of producing a rotor having low resistance, high mechanical strength, and ability to permanently withstand vibration and centrifugal force without excessive heating, all of which are essential factors in an efficiently operated squirrel-cage induction motor.

WELDING ELBOWS ON LIBERTY CYLINDERS

In making Liberty motors in the Ford shop, the valve elbows were butt-welded on as shown in Fig. 220. The holding

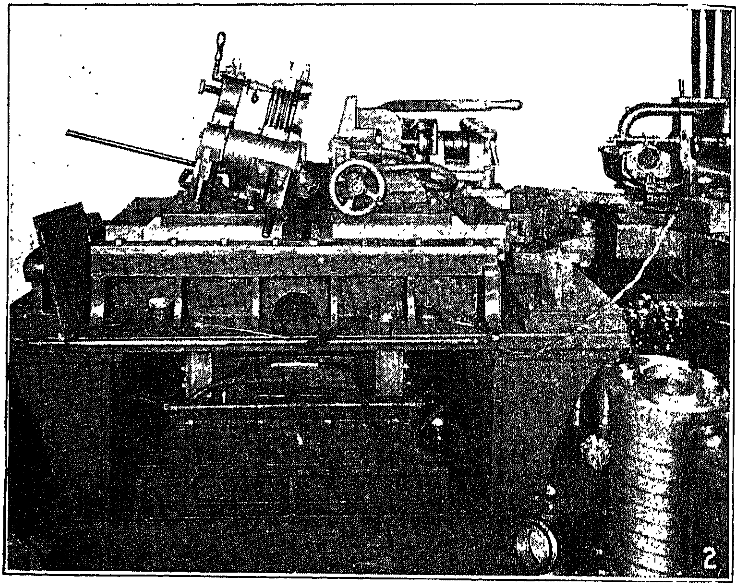


FIG. 220.—Welding Valve Elbows.

fixture is shown with the hinged top thrown back and a cylinder in the cradle. One elbow has already been welded on, and the other is held in the jaws of the sliding fixture, ready to be welded in place. This work was done before the cylinders were finish bored and by so doing all cylinder distortion, due to welding was cut out in the finish boring.

An automatic straight-link chain making machine, built by the Automatic Machine Co., Bridgeport, Conn., is shown in

Fig. 221. This machine took the material from a reel, shown at the right, formed it, butt-welded the ends of the links and turned out the chain as indicated. The machine was so made that the welded part of each link was pressed between special dies while still hot, the operation practically eliminating the

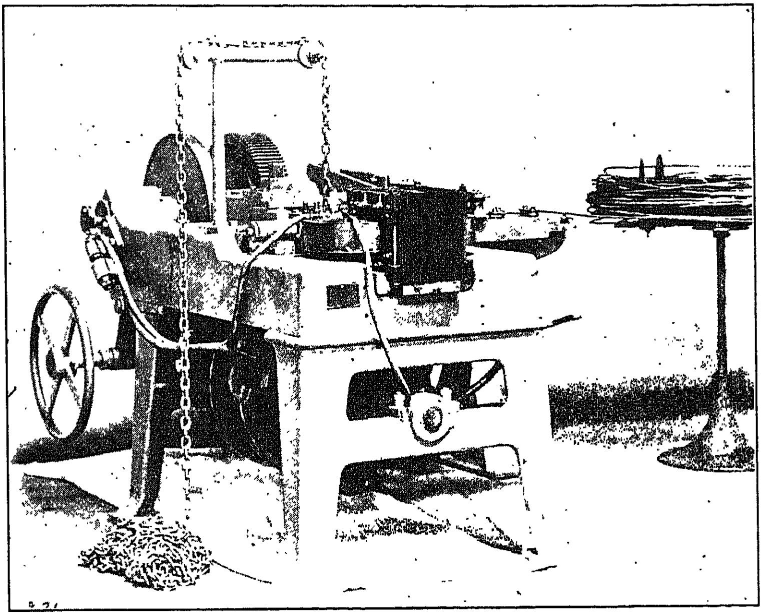


FIG. 221.—Automatic Chain Making Machine.

flash formed in welding. Aside from the welding features, the machine was a marvel of mechanical ingenuity and simplicity.

ELECTRO-PERCUSSIVE WELDING

The joining of small aluminum wires has always presented much difficulty on account of the oxide film which prevents the metal parts from flowing together, unless brought to a point of fluidity at which the oxide film can be broken up and washed away. If this be attempted with small sections, the whole mass is likely to be oxidized, and the resulting joint will be brittle or "crumbly."

In 1905 L. W. Chubb, of the Westinghouse Electric and Manufacturing Co., Pittsburgh, Penn., discovered that if two

pieces of wire were connected to the terminals of a charged condenser, and then brought together with some force, that enough electrical energy would be concentrated at the point

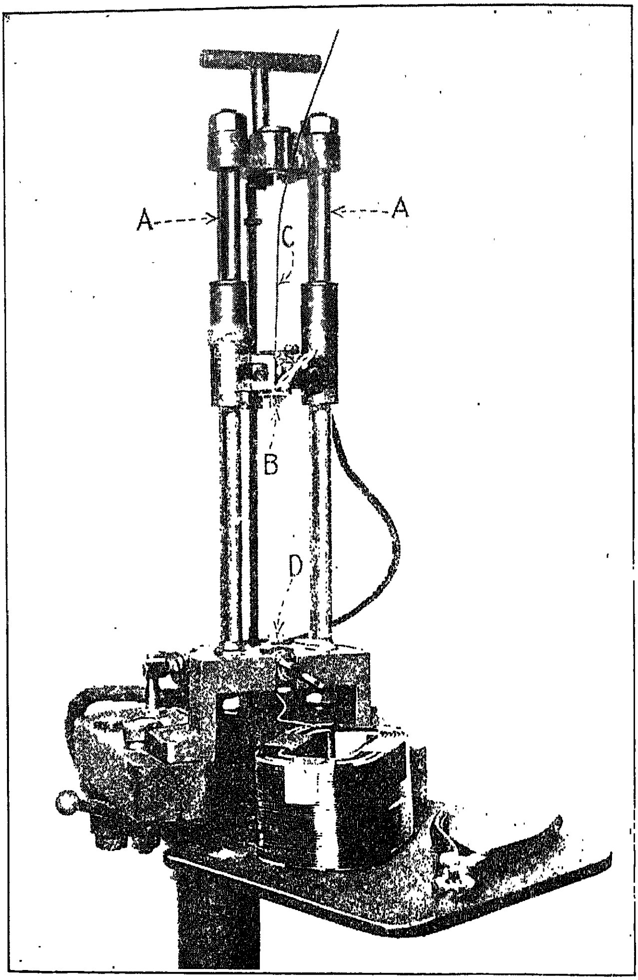


FIG. 222.—Electro-Percussive Welding Machine.

of contact to melt the wires, while the force of the blow would weld them together. Accordingly, a welding process was developed and used by the Westinghouse company, and

machines made which are capable of welding all kinds of wire up to No. 13 gage. The process was called electro-percussive

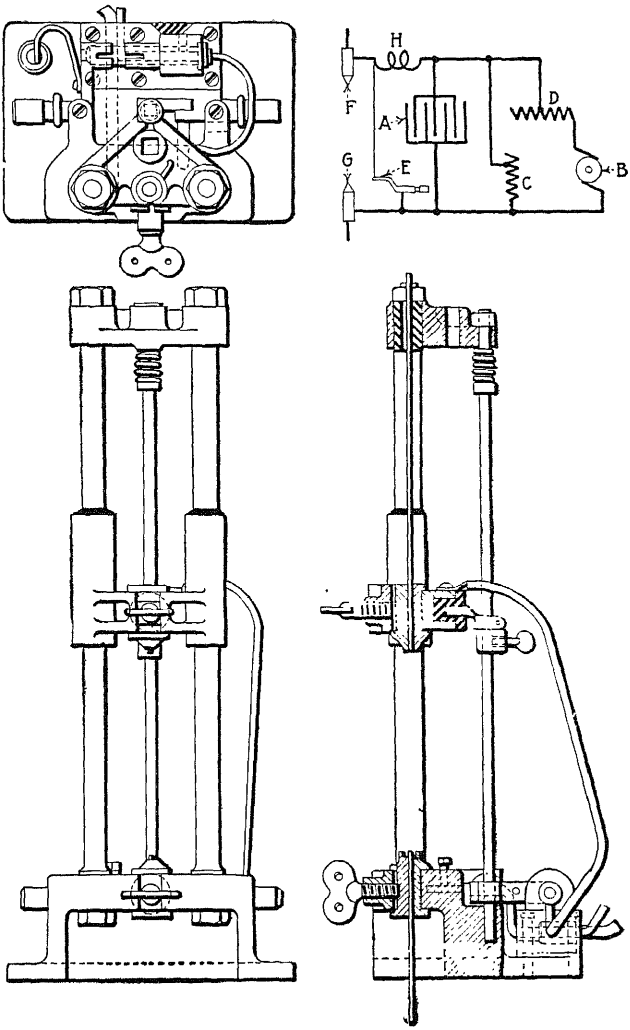


FIG. 223.—Details of Percussive Welding Machine and Wiring Diagram.

welding and a machine for doing the work is shown in Fig. 222. This machine has vertical guides *A* between which travels

a chuck *B* holding one wire *C*. The other wire is held below in chuck *D* in such a position that the end of the moving wire strikes it squarely. Each chuck is connected by flexible cable to a circuit as shown in Fig. 223. An electrolyte condenser *A*, shown in the wiring diagram, is connected across a source of direct current from *B*, which charges it to a potential determined by the resistances *C* and *D*. A switch *E* keeps the chucks *F* and *G* at the same potential during placement and removal of work.

After the wires to be welded have been chucked, they are clipped short by a cutter which gives each a chisel, or wedge-shaped end. These ends are set at right angles to each other. The switch is opened and the sliding chuck is released and allowed to fall. At the instant when the two narrow edges come into contact, the current discharged generates intense heat at the center of the section. The metal melts and is forced out by the impact and eventually the entire surface of each wire is melted. Due to the very large body of cold metal adjacent, the thin film of molten metal solidifies quickly and since it is under momentarily heavy pressure it forms a homogenous mass absolutely continuous with the wires on each side. In practical operation, the inductance *H* is required to lower the rate at which the condenser discharges, that is, to maintain the current at a lower rate until the entire surface of the weld has been forced into contact. The correct action can be told by the sound made by the contact. It should be a splash or thud, rather than a sharp crack. The mass and drop of the falling part must be great enough to slightly forge the material. Once set for the proper drop, the machine will make a perfect weld every time.

Actual tests on two No. 18 B. & S. aluminum wires, using an oscillograph, show that the power being expended at the weld reaches a value of 23 kw. for an instant. However, the entire weld is made in 0.0012 sec., and the total energy used at the weld is 0.00000123 kw.-hr. The cost of this weld, figured at 10 cents per kw.-hr., would be twelve millionths of a cent.

A chart of the oscillograph aluminum-wire test just referred to, is shown in Fig. 224. At *A* the right-angled chisel-ends are shown almost in contact as the upper chuck falls. As the ends contact at *B* the voltage drops as indicated by the curve

G, but the current and power consumption suddenly increases as shown by the curves *H* and *I* respectively.

At *C* the wire ends have separated, caused by the melting and vaporizing of the chisel edges. At *D* the chucks are closer together but the arc is still burning away the wire ends. At *E* the second contact has been made, the arc eliminated and upsetting begun. At *F* the weld is shown completed.

One of the principal uses for this process is in welding copper to aluminum, as for example copper lead-wires to

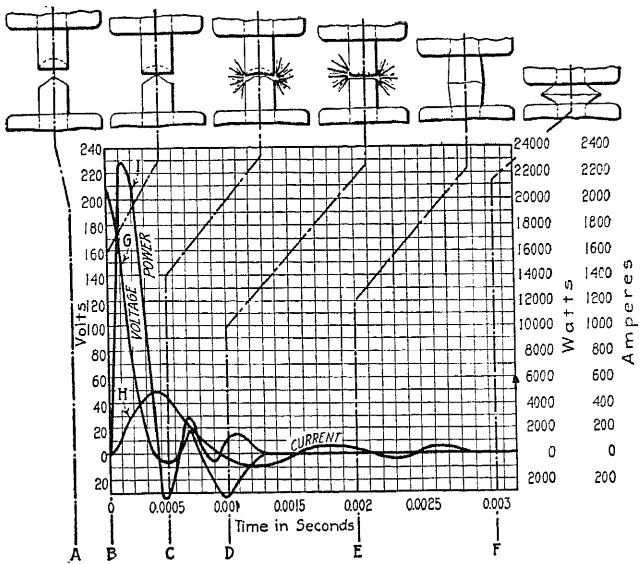


FIG. 224.—Chart of Oscillograph Test on 18 B. & S. Gage Aluminum Wire, Showing Power Consumed and Time to Complete a Percussive Weld.

aluminum coils. The advantage of copper for connecting is self-evident, as it is easily soldered. It was thought at first that a weld of the two metals would result in a brittle joint, but tests show that after several years the joint is apparently as strong and ductile as when first made. Similar ductility has been noted in almost every combination of metals when first welded, but disintegration and loss of ductility eventually result in such welds as silver to tin or aluminum to tin, the welds being affected by what is known as "tin disease" or "tin pest"—a disintegration of the molecules.

Alloy of practically any composition can be welded to each other, and there is little diffusion of one metal into the other across the welded surface. Thus this method is quite suitable

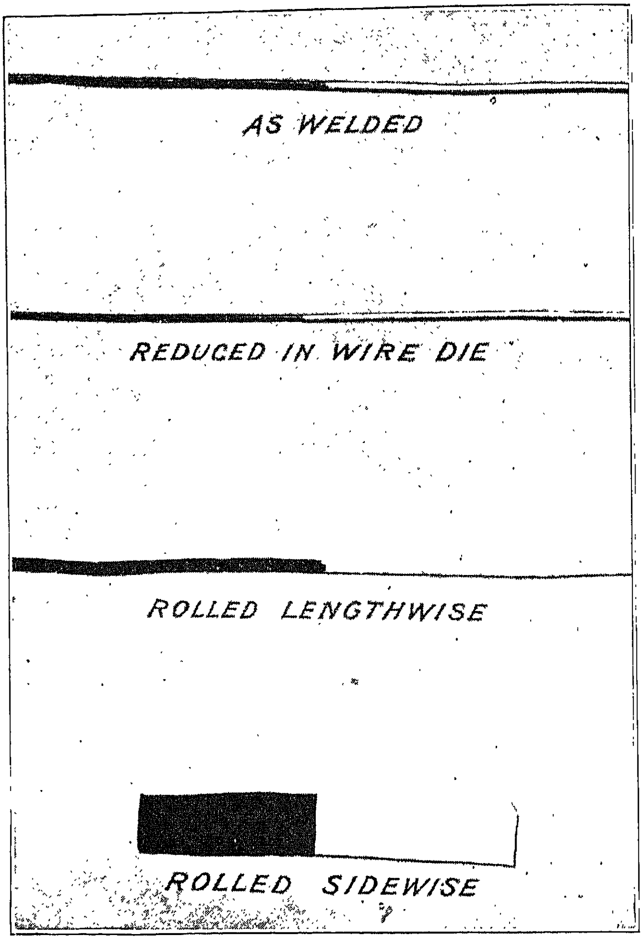


FIG. 225.—Copper Welded to Aluminum.

for *attaching contact points to flat plates* and making small welds required by jewelers.

Another important quality of the process is that metals which soften with heating, such as hard-drawn copper and

silver, can be welded without change of condition since the length of metal heated to an annealing temperature will not be more than 0.004 in. long and this amount of metal is negligibly small. As will be seen from the specimens in Fig. 225, which show copper welded to aluminum, then drawn and rolled, there is no loss of ductility at the weld and no tendency for the two metals to separate.

CHAPTER XIII

SPOT-WELDING MACHINES AND WORK

Spot welding, as the name indicates, is simply welding in spots. Two or more overlapping metal plates or sheets may be welded together at intervals, by confining electric current to a small area of passage by means of suitable electrodes, or "dies" which are pressed against the metal from opposite sides. Spot welding is a form of resistance welding. Due to the way the metal is heated and forced together no oxidizing takes place, and in consequence no flux of any kind is needed.

While the process of spot welding is more commonly used at present for welding thin sheet iron, steel or brass articles, practical machines have been made for welding two pieces of ¾-in. ship plate together. Experimental machines have also been made capable of spot-welding three 1-in. plates together, and which can exert a pressure of 36 tons and have a current capacity of 100,000 amperes.

To weld soft cold-rolled steel in a satisfactory commercial manner, three conditions should be observed, if possible:

First, the surfaces to be welded should be free from rust, scale or dirt. If the work is not clean a higher secondary voltage will be required to penetrate through the scale or dirt of any given thickness of sheet. This means that a larger machine and more current must be used than would be required for clean stock of the same thickness.

Second, the sheets should be flat and in good contact at the spots to be welded, so that no great pressure is required to flatten down bulges or dents.

Third, the stock should not surround the lower horn, as in the case of welding the side seam of a can or pipe.

It must not be understood that spot welding cannot be done except under the conditions outlined, for it can, but if the conditions named are not followed the cost of welding will be greater. However, it is often necessary to violate these

conditions in actual manufacturing work. This is especially true of the third one. Where the lower horn must be surrounded by the work, as in welding can seams, the capacity of the machine is cut down because of the "induction effect" which tends to choke back the main current and in this way cuts down the heating effect at the die points. This so-called induction effect is only present when welding steel or iron, no such action being noticeable in welding brass.

Light gages of sheet metal can be welded to heavy gages or to solid bars of steel if the light-gage metal is not greater than the rated single sheet capacity of the machine. Soft steel and iron form the best welding material in sheet metals, although it is possible to weld sheet iron or steel to malleable-iron castings of a good quality.

Galvanized iron can also be welded successfully, although it takes a slightly longer time than clear iron or steel stock, in order to burn off the zinc coating before the weld can be made. Contrary to common opinion, the metal at the point of weld is not made susceptible to rust by this burning off of zinc, since by some electrochemical action it has been found that the spots directly under each die-point and also around the point of weld between the sheets, are covered with a thin coating of zinc oxide after the weld has taken place. This coating acts as a rust preventive to a very noticeable degree. On spot-welded articles used in practice for some time, such as galvanized road-culverts, refrigerator-racks and pans, rain-gutters, etc., it has been found that no trace of rust has appeared on the spot-welds from their exposure to ordinary atmospheric conditions. Extra light gages of galvanized iron below 28 B. & S. gage cannot be very successfully welded, due to the fact that so little of the iron is left after the zinc has been burnt off that the metal is very apt to burn through and leave a hole in the sheets.

Tinned sheet iron is ideal for welding, giving great strength at the weld, but the stock will be discolored over the area covered by the die-points. Sheet brass can be welded to brass or steel if it contains not more than 60 per cent copper. It is not practical to attempt to spot-weld any bronze or alloy containing a higher percentage of copper than this as the weld will be weak.

Another class of work that can be successfully handled on a spot-welding machine, although it is not strictly spot welding, is the construction of wire-goods articles. This consists principally in "mash-welding" crossed wires. It may be done with the same copper die-points as are used for ordinary spot welding, except that the points are usually grooved to hold the wire in the required position. Among the common wire goods put together in this way are lamp-shade frames, oven

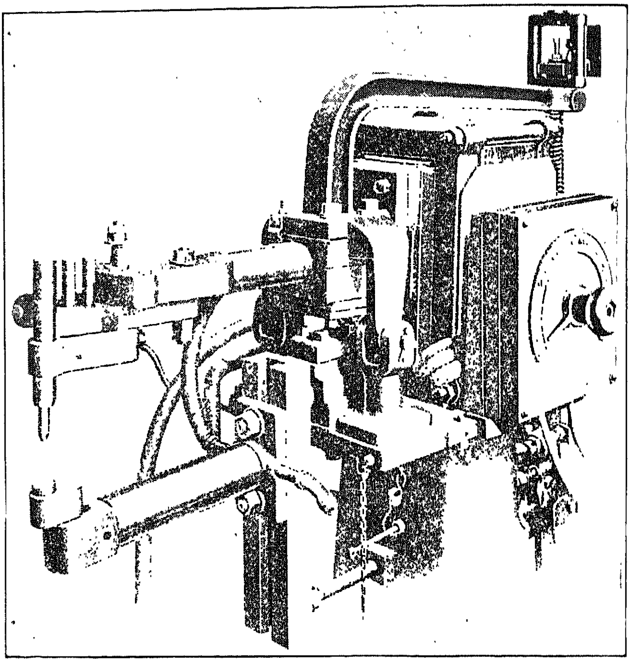


FIG. 226.—Typical Construction of Light Spot-Welding Machine.

racks, dish drainers, waste baskets, frames for floral make-ups and so on. Certain classes of butt-welding may also be done on a spot-welding machine by using special attachments.

Details of Standard Spot-Welding Machines.—Spot-welding machines are made in various sizes and designs to meet different requirements, but the general principle of action is the same in all. The illustration, Fig. 226, shows a Thomson No. 124-A10 machine with the cover removed. This gives an idea of the principal mechanism of all this line of light spot-welding

machines. Fig. 227 shows a typical head of one of their line of heavier machines. This type of machine is designed for heavy work on flat sheets or pieces, where considerable pressure is required to bring the parts together to be welded. To withstand heavy pressures, the lower horn is made of T-section cast iron and the current is conducted to the lower copper die-holder by flexible copper laminations, protected on all sizes

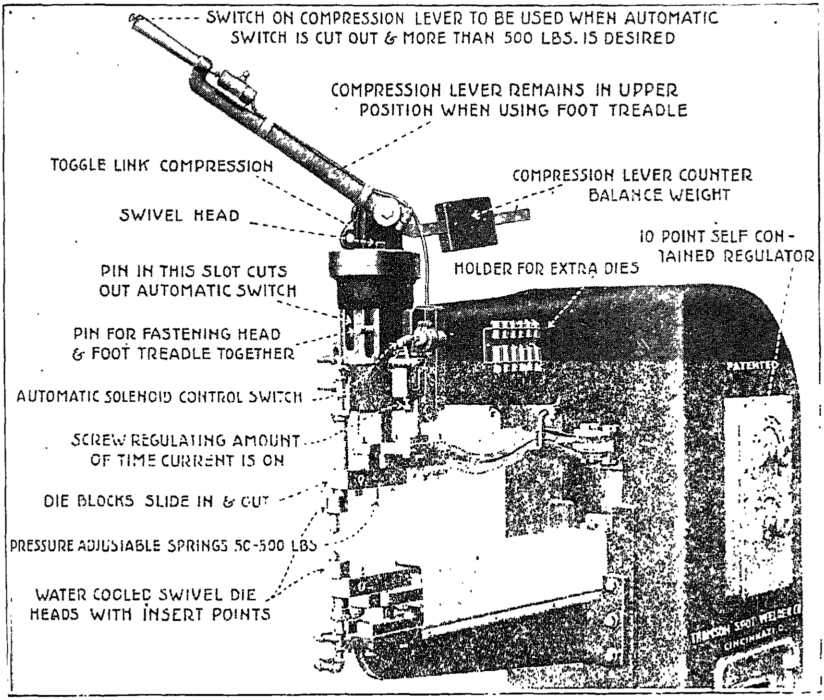


Fig. 227.—Spot-Welding Machine for Heavy Work, with Parts Named.

having over 15-in. throat, by a brass cover, insulated on the inside from the copper by a coating of asbestos sheet.

The sliding head of the machine which carries the upper die-holder is a hollow steel plunger, sliding in a cast-iron head, which bolts to the body of the machine and on which are mounted the control-switches. The pressure is applied by a toggle-motion above the plunger, actuated both by a swiveled hand-lever on top of the head, which may be swung into any

position through an arc of 260 deg., and a foot-treadle at the base, which also may be swung in an arc of 30 deg. This enables the operator to control the machine by hand or foot from any position around the front of the machine.

The current-control can be set to work automatically with the downward stroke of the upper die. In this case the pressure at the die-point is through an adjustable spring-cushion in the hollow cylinder-head. The current is automatically turned on after the die-points have come together on the work by further downward pressure of either lever. With the application of final pressure, to squeeze out any burnt metal as the weld is forced together, the current is automatically turned off. When working on pieces where more pressure is required to bring the parts together before welding than can be effected by the spring-cushion without turning on the current, it is possible to set a plug in the head of the machine so that direct connection is obtained from the hand-lever to the upper die-point while the foot-treadle still operates through the spring-cushion and with the automatic current-control. When it is desired to secure maximum pressure, the plug in the head can be set again so that both the hand-lever and the foot-treadle give direct connection to the die-point, the current being controlled by a push-buttom on the outer end of the hand-lever.

The regular line of spot-welding machines of different makes, operate on 110-, 220-, 440- and 550-volt, alternating current. A welding machine of this kind can only be connected to one phase of an a.c. circuit. The transformer must be made to furnish a large volume of current, at a low voltage, to the electrodes. For further transformer details, the reader is referred to the article on butt-welding.

The Thomson Foot-, Automatic-, and Hand-Operated Machines.—The machine shown in Fig. 228 is representative of the Thomson line of small, foot-operated spot-welding machines. These are intended for use on light stock where but little pressure is required. The die-holders are water-cooled, and the lower horn bracket allows the horn to be adjusted up or down for the use of various kinds of holders. The automatic switch and adjustable throw-in stop are plainly shown at the back of the machine.

The model is made in several sizes. The first size will weld from 30 to 16 B. & S. gage galvanized iron or soft steel, or to 24 gage brass. It will mash-weld wire from 14 gage to $\frac{1}{4}$ in. in diameter. Its throat depth is 12 in.; the lower horn drop clearance is 9 in.; size is 22×45×51 in. high; net weight

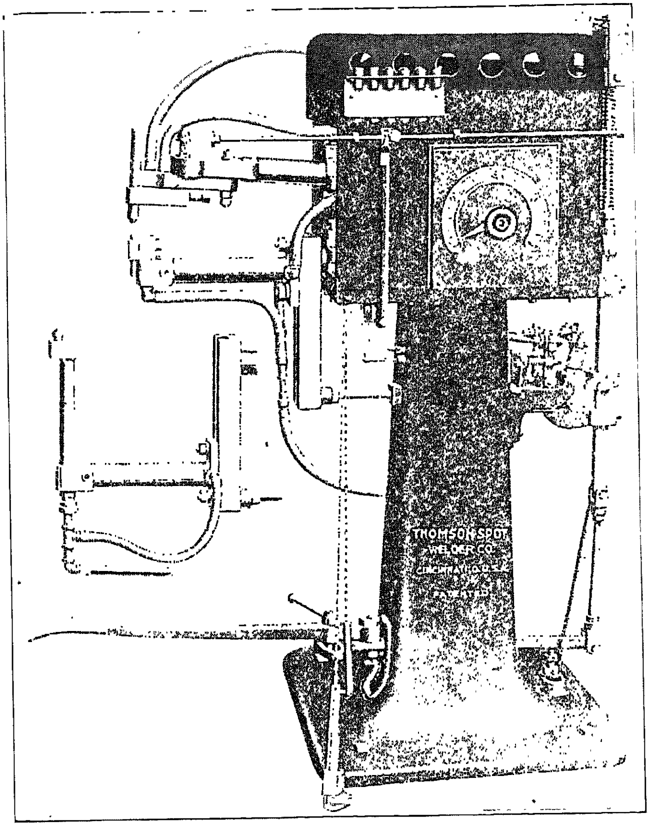


FIG. 228.—The Thomson Light Manufacturing Type Spot-Welding Machine.

is 825 lb.; full load rating is 5 kw., or 8 kva. The largest machine of this particular series, will weld 26 to 7 gage, B. & S., galvanized iron or soft steel, or 18 gage brass; it will mash-weld 10-gage to $\frac{3}{8}$-in. diameter wire; has an 18-in. depth of throat; is 28×60×56 in. high; weighs 1,550 lb. and full load rating is 15 kw. or 25 kva.

On repetition work, where the operator has to work the foot-treadle in rapid succession for long periods, it is very tiresome. For such work, power-driven machines similar to the one shown in Fig. 229 are made. These machines are supplied either with individual motor drive or pulley drive, as desired. The control is effected through the small treadle shown. The regular foot-treadle is used while setting up dies,

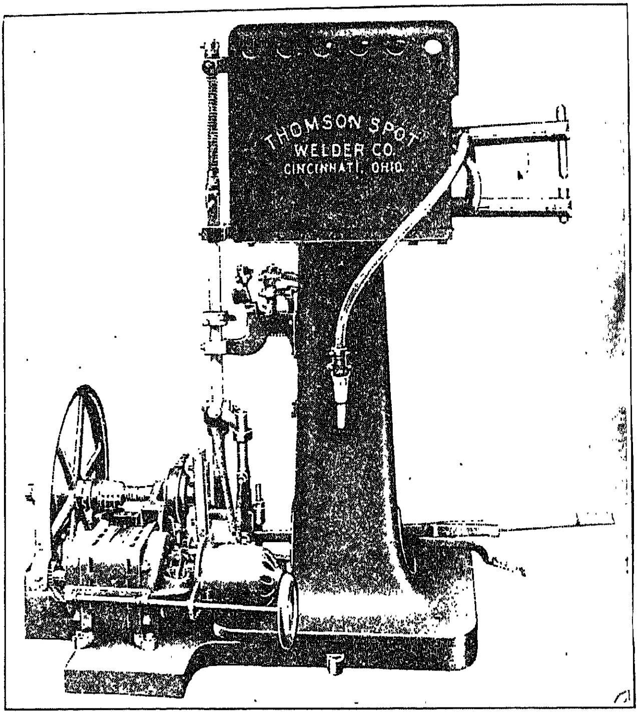


FIG. 229.—The Thomson Semi-Automatic Type Spot-Welding Machine.

etc. If the operator desires to make but one stroke, he depresses the shorter treadle and immediately releases it, whereupon the machine performs one cycle of operation, automatically turning on the current, applying the pressure, turning off the current, and stopping. A $\frac{1}{4}$- to $\frac{1}{2}$-hp. operating motor is used according to the size of the machine. Otherwise the capacity of the various sizes is the same as in the regular foot-operated

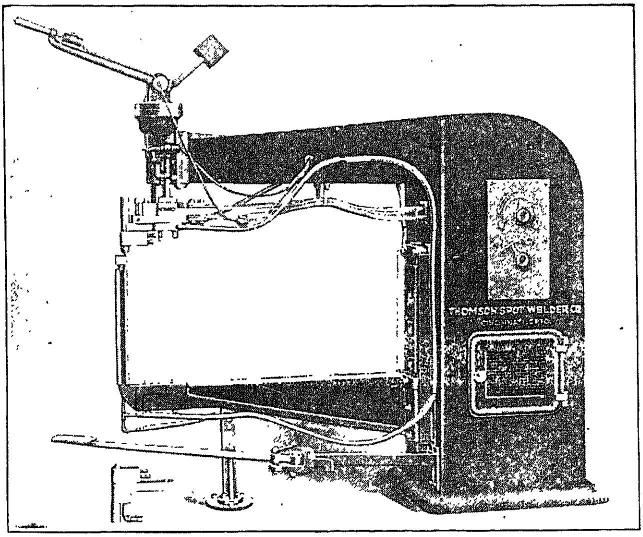


FIG. 230.—A Thomson Heavy-Duty Spot-Welding Machine.

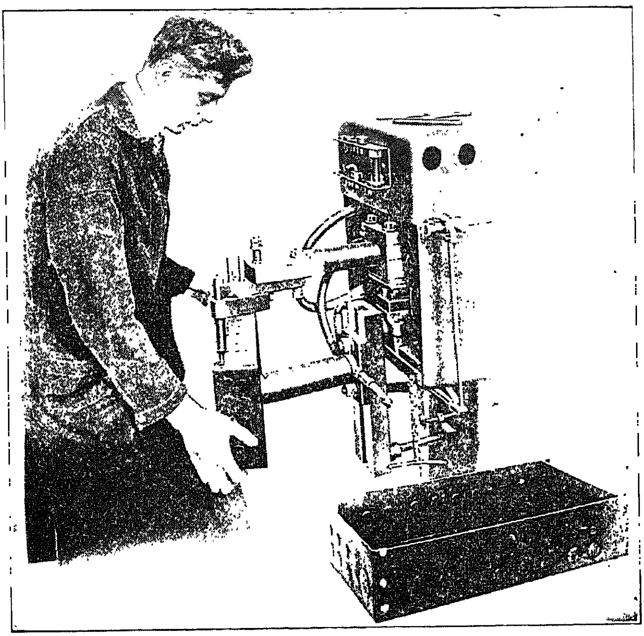


FIG. 231.—Spot-Welding a Sheet Steel Box.

machines. The lower horn and upper arm may be of either style illustrated.

The machine shown in Fig. 230 is a hand-lever operated machine, although supplied with a foot-treadle which can be

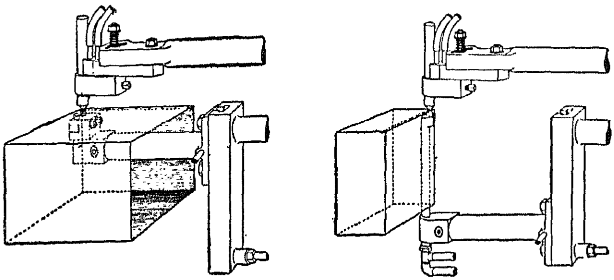


FIG. 232.—Showing How the Horn and Welding Points May Be Set.

swung back out of the way when not needed. This machine is typical of the Thomson designs used for the heavier run of commercial work. On the various sizes, the capacity for spot-welding is from 22 B. & S. gage galvanized iron or steel

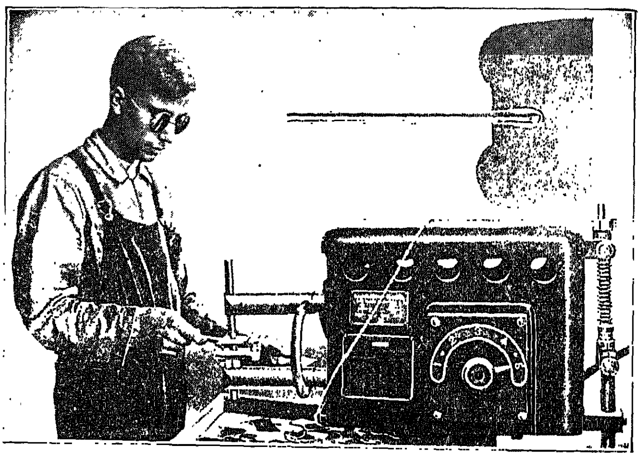


FIG. 233.—Welding Small Hoe Blades to the Shanks.

up to No. 0 gage, or to 14 gage brass. Mash-welds may be made on from $\frac{1}{8}$- to $\frac{5}{8}$-in. diameter wire. The throat capacities run from 15 to 51 in. and the lower horn adjustment is from 12 to 24 in. The smallest size is 28×62×75 in. high and the

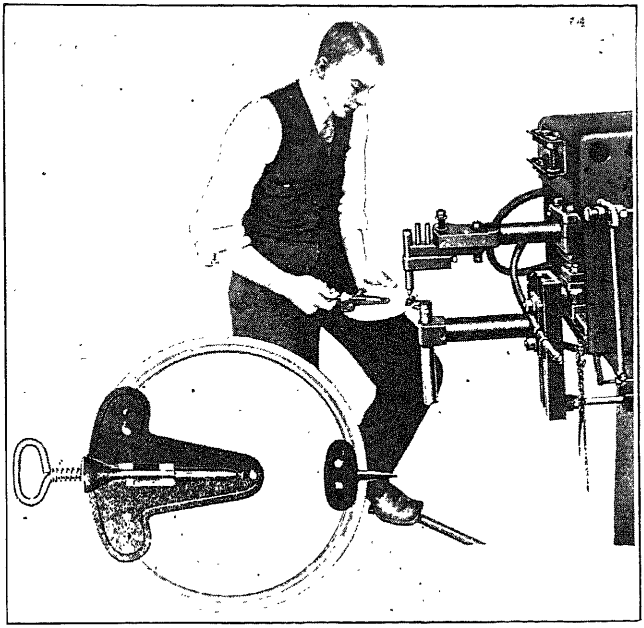


FIG. 234.—Welding Stove Pipe Dampers.

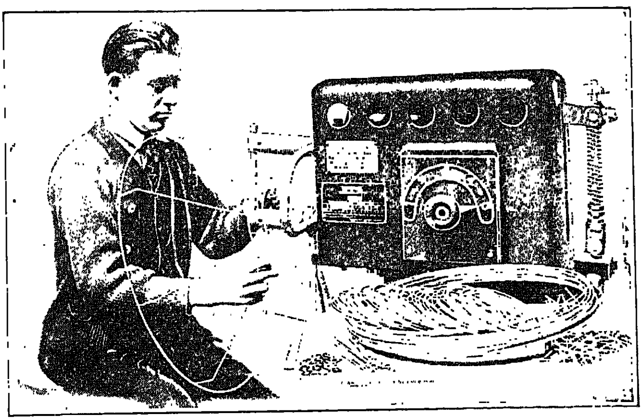


FIG. 235.—Mash-Welding Lamp Shade Frames.

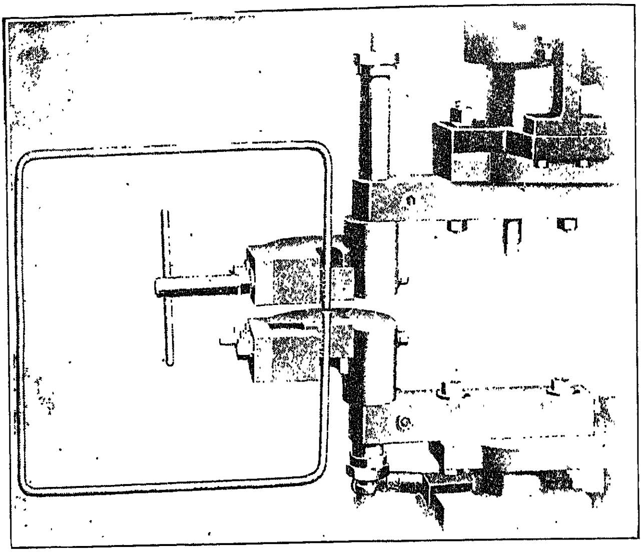


FIG. 236.—Butt-Welding Attachment for a Spot-Welding Machine.

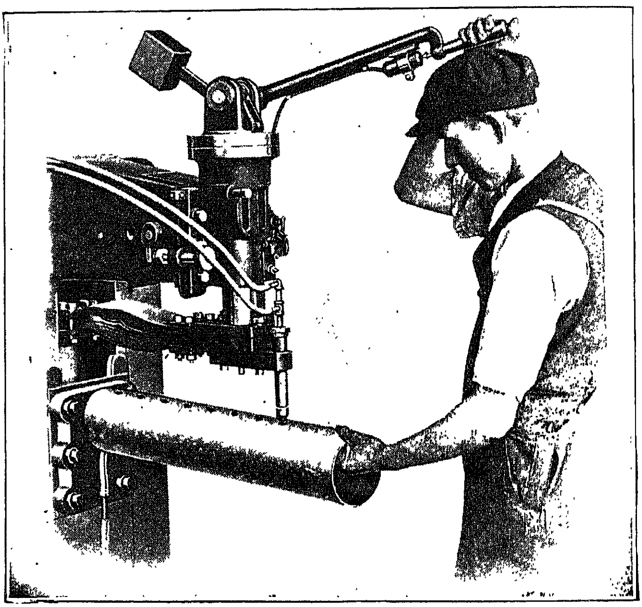


FIG. 237.—Welding Galvanized Iron Pipe.

largest size 28×98×75 in. high. The weights run from 2,335 to 3,225 and the full load ratings from 20 to 40 kw. or 35 to 67 kva. Various shaped horns, dies and other equipment are furnished to meet special demands.

Examples of Spot-Welding Work.—In connection with the Thomson machines, the welding of the corners of a sheet-steel box is shown in Fig. 231. The illustrations in Fig. 232 show how the lower horn is raised for welding side seams and dropped for welding on the bottom of a box.

The welding of small hoe blades to the shanks is shown

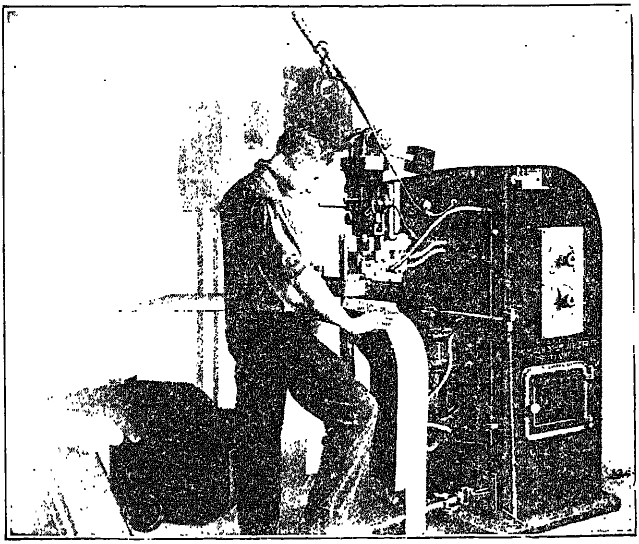


FIG. 238.—Welding 12-Gage Iron for Guards.

in Fig. 233. These are welded at the rate of 840 per hour, the shanks being bent afterward. Stove-pipe dampers are welded as shown in Fig. 234, and wire lamp-shade frames are mash-welded as shown in Fig. 235. Ordinary wire and sheet-metal oven gratings or racks, with seven cross-wires welded to the end pieces, have been made at the rate of 100 racks per hour, or 1,400 mash-welds. On certain kinds of wire work, it is desirable to butt-weld, and for this purpose the attachment shown in Fig. 236 is used. In general, however, where any amount of this kind of work is to be done, it is better

to employ a regular butt-welding machine of the small pedestal or bench type.

The spot-welding of galvanized ventilating pipe is shown in Fig. 237, and in Fig. 238 is shown the welding of 12 gage sheet steel machine guards. In this illustration the operator is using the foot-treadle which leaves his hands free to manipulate the work. In Fig. 239 the operator is welding gas-stove parts and the foot-treadle is thrown back out of the

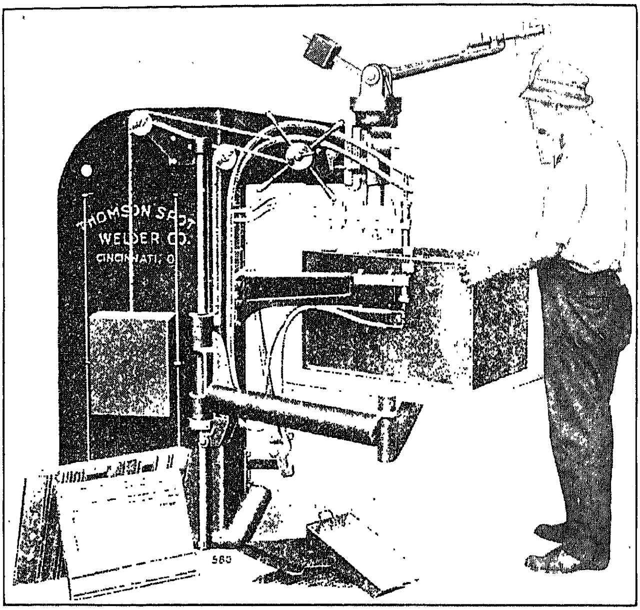


FIG. 239.—Welding Stove Parts, Using a Swinging Bracket Support.

way. A special bracket is employed to hold the work. The joints of this bracket are ball-bearing, making it very easy to swing the work exactly where it is wanted to obtain the spot-welds.

POINTS FOR SPOT WELDING

The form of spot-welding points shown in Fig. 240, says A. A. Karcher, has been developed by the Challenge Machinery Co., Grand Rapids, Mich., with gratifying results. Fig. 241 shows a typical weld and indicates the neatness, slight dis-

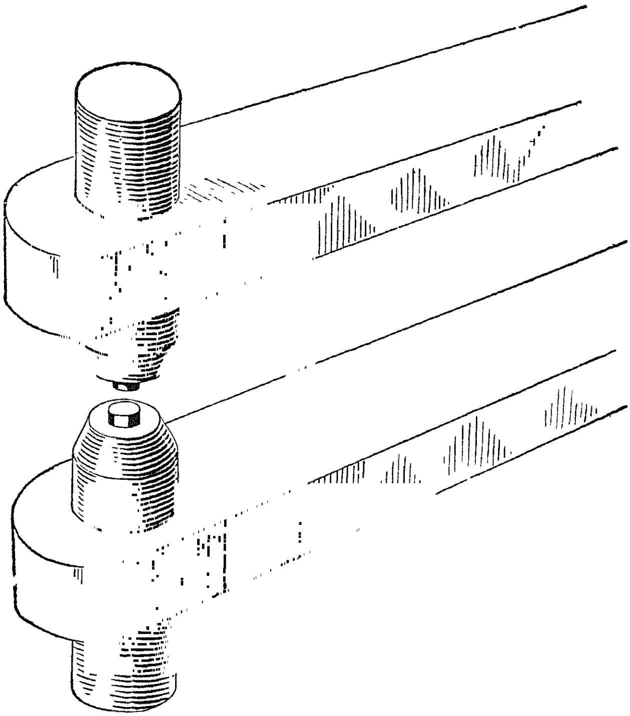


FIG. 240.—Form of Points for Spot Welding.

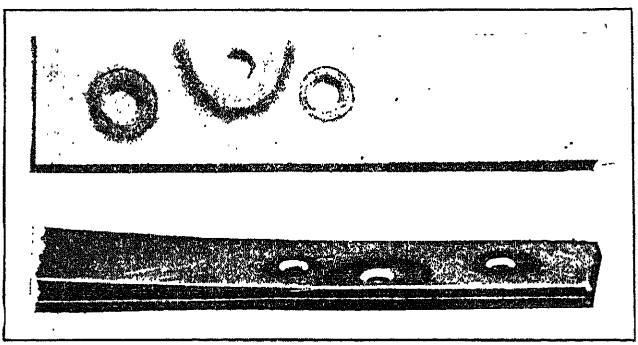


FIG. 241.—Spot Weld Showing Slight Discoloration and Freedom from Flash.

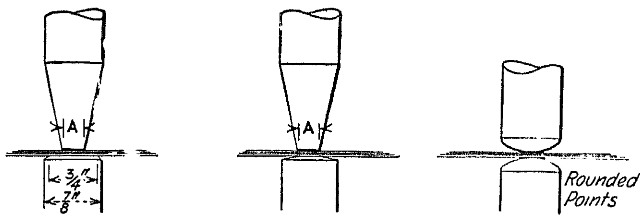
coloration of the metal and entire freedom from flash either on the outside or between the parts. In one view the discolorations give an erroneous impression of the existence of bosses on the face of the metal, which is actually flat except for the depressions at the points of the welds.

The shape of the points would lead one to expect that the small projections would require a lot of attention to keep them in shape. Experience shows, however, that this is not the case, as the points actually lengthen slightly and occasionally have to be filed down.

Even when a weld is made close to the edge the operation is quicker and consumes less current. A little practice in determining the correct amount of current to use is all there is to learn in handling these points.

SIZES OF DIE-POINTS FOR LIGHT WORK

The data on the size of die-points in Fig. 242 are given on the authority of Lucien Haas, and may be considered good



GAGES	A
28-26-24-22	1/8"
20-18-16	3/16"
14-12	1/4"

IRON AND STEEL	
GAGES	A
11-10	1/4"
9-8-7	5/16"
6-5-4	3/8"
3-2-1-0	1/2"

GALVANIZED IRON	
GAGES	A
22-20	1/8"
18-16-14	3/16"
12-10	1/4"
9-8-7	3/8"

FIG. 242.—Sizes of Die Points for Light Work.

general practice. These points are intended for welding two pieces of the same gage and material.

On certain kinds of heavy spot-welding work circular metal disks are placed between the plates in order to localize the current and to provide good contact. In other cases, projections are made in one or both of the plates. These latter, of course, necessitate a mechanical or press operation, previous

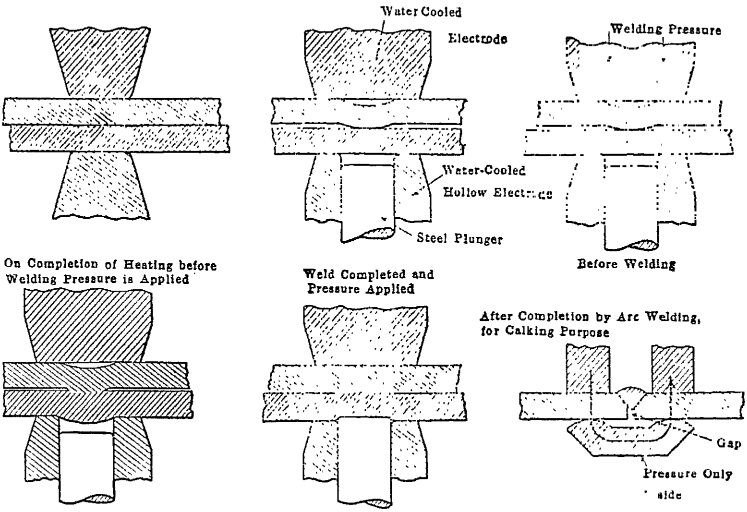


FIG. 243.—The Tit or Projection Method of Welding.

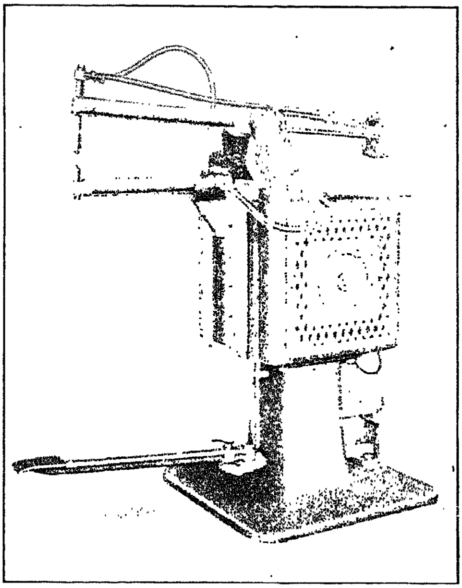


FIG. 244.—Winfield Sliding Horn Spot-Welding Machine.

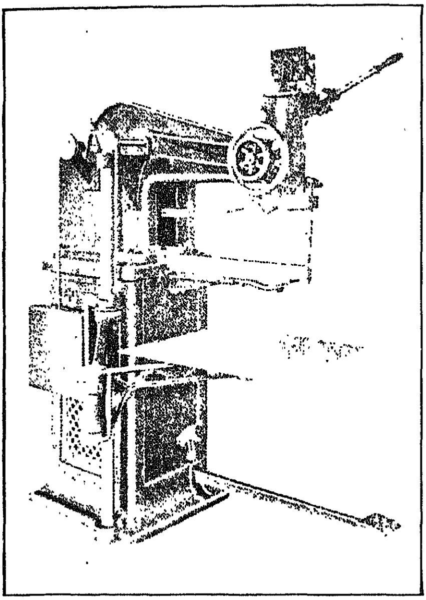


FIG. 245.—Winfield Heavy-Duty Machine with Adjustable Table.

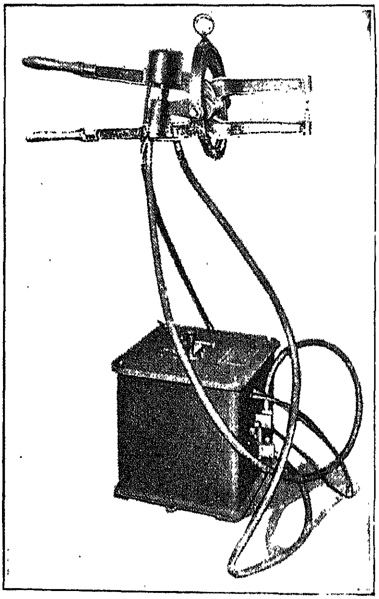


FIG. 246.—Winfield Portable Spot-Welding Machine.

to welding. Heavy plate work is shown in Fig. 243. At the upper left are shown plates as commonly arranged for welding. Next to this is a plate with a projection under the upper die-

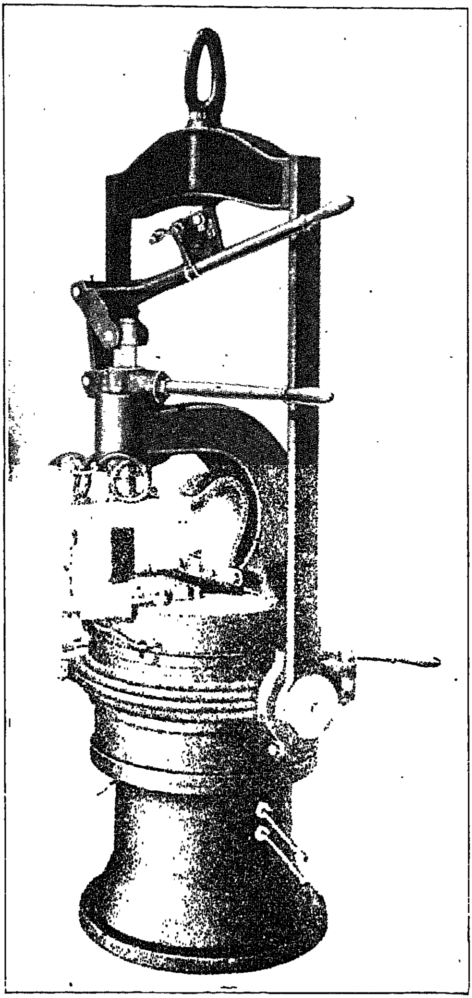


FIG. 247.—Winfield Portable Machine with Swivel Head.

point. A steel plunger is used in the lower die to give the needed pressure after the metal is heated. This saves crushing or distorting the soft copper. In the lower right-hand corner

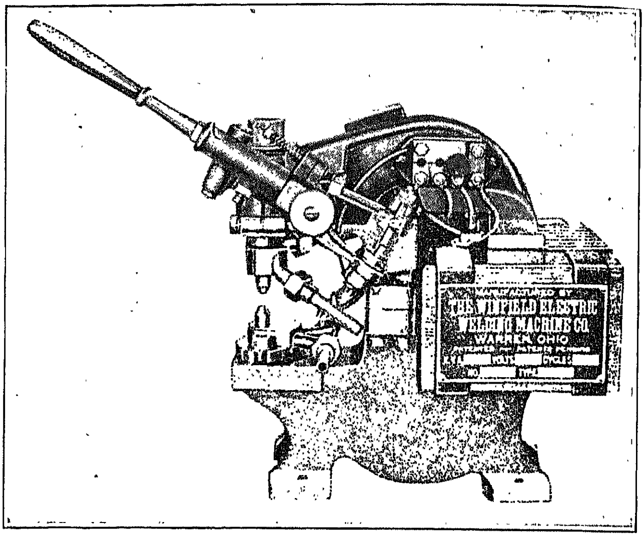


FIG. 248.—Small Winfield Bench Machine.

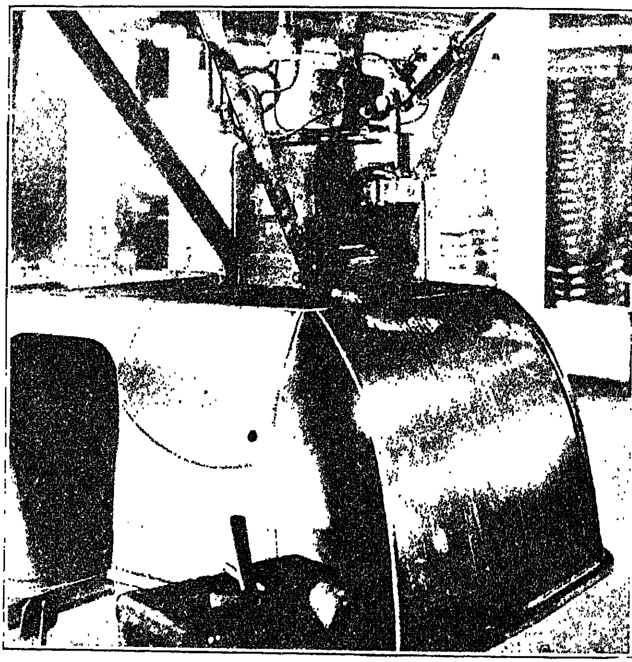


FIG. 249.—Winfield Machine with Suspended Head for Welding Automobile Bodies.

is shown a ridge or tit weld, after the seam has been arc-welded.

The Winfield Machines.—The machines made by the Winfield Electric Welding Machine Co., Warren, Ohio, comprise a varied line for every conceivable spot-welding purpose. In general, Figs. 244 and 245 may be taken as typical of their

FIG. 250.—Convenient Setting of Machine for Sheet Metal Work.

light and heavy spot-welding machines. Fig. 246 shows a very convenient form of portable machine. In Fig. 247 is shown a much heavier portable machine with swiveling head, and in Fig. 248 is a small bench machine that is exceedingly useful for light work.

A very interesting machine is shown in Fig. 249. This has the entire head suspended from the ceiling, so that work, like the automobile body shown, may be worked under it.

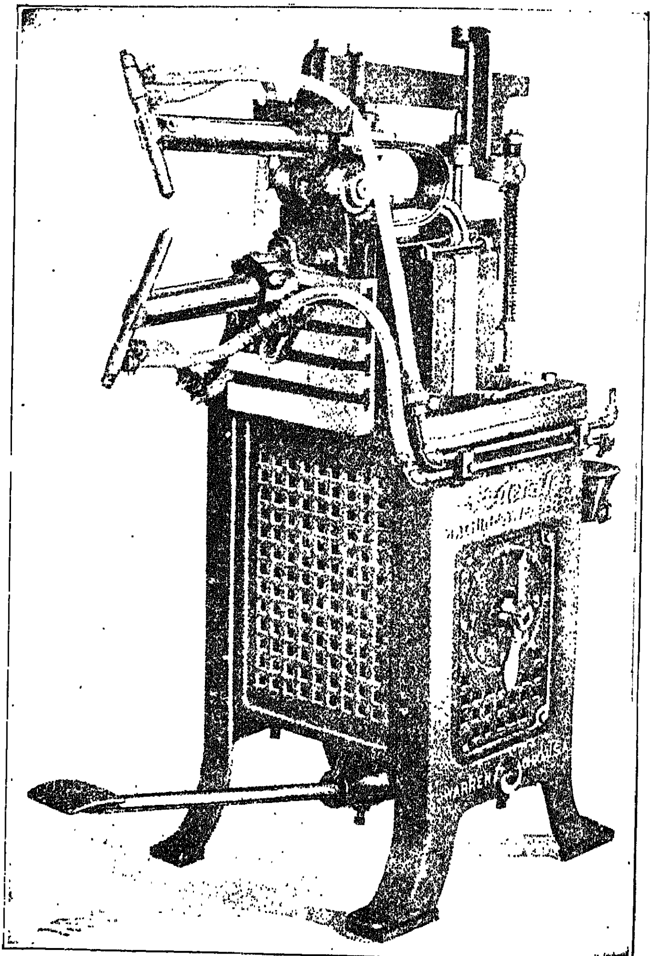


FIG. 251.—Federal Welding Machine with Universal Points.

This machine is in use in the plant of the Herbert Manufacturing Co., Detroit.

A good way to place a machine for some work is shown in Fig. 250. This is employed in the shop of the Terrell

Equipment Co., Grand Rapids, Mich., in the manufacture of steel lockers, steel furniture and the like.

Federal Welding Machines.—A feature of the spot-welding machines made by the Federal Machine and Welder Co., Warren, Ohio, are the "universal" welding points used on most of their output. The principle will be instantly grasped by

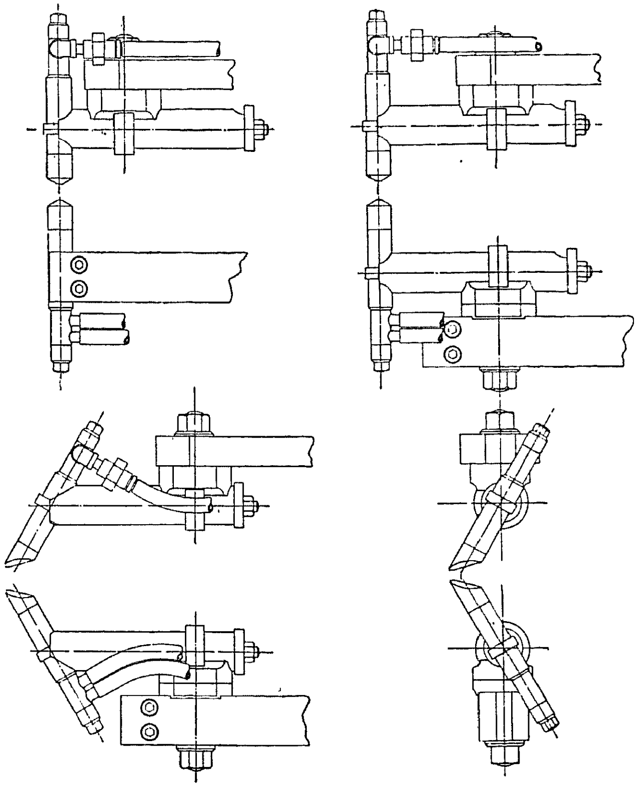


FIG. 252.—A Few Positions of the Universal Points.

referring to Fig. 251. Some of the different positions possible are shown in Fig. 252.

Another feature of these machines, is the use of the type of water-cooled points shown in Fig. 253. The welding point is copper and it is attached to the holder in such a way that the water flows within half an inch of the actual welding contact.

In general form, size and capacities, the Federal line does not differ materially from the machines already shown.

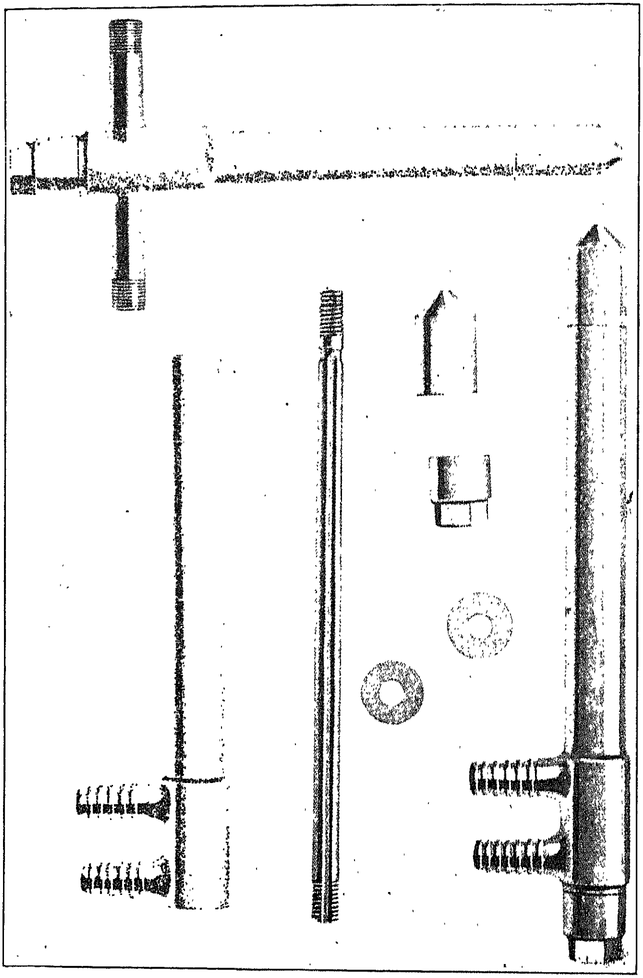


FIG. 253.—Federal Water-Cooled Points.

FEDERAL ROTATABLE HEAD TWO-SPOT WELDING MACHINE

The rotatable head two-spot, air operated welding machine, shown in Fig. 254, a 60-in. throat depth and is guaranteed to weld from two thicknesses of 24-gage up to two thicknesses

of 8-gage steel stock. Twelve welds per minute may be made in the latter size.

The machine is built with a 4 kva. welding transformer in the upper and lower rotating heads. Primaries are in parallel while the secondaries are in series. so that two spot welds must be made at the same time.

The welding electrodes or points are $1\frac{1}{2}$ in. in diameter, are carried in water-cooled holders, and are so arranged that

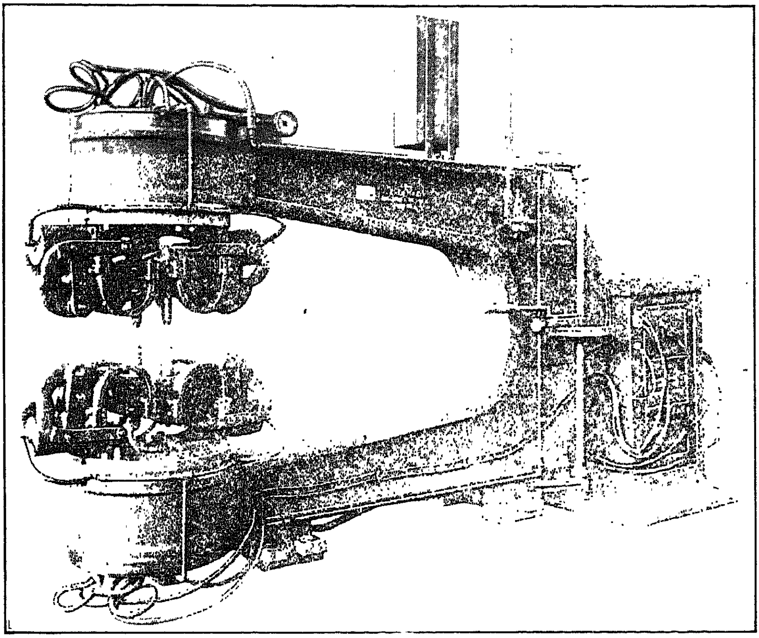


FIG. 254.—Federal Rotatable Head Two-spot Welding Machine.

welds from 3 to 8 in. apart may be made. The ends of each set of welding points can be separated a maximum of 5 in. The heads can be rotated through an angle of 90 deg. to permit welding at different angles on the stock being handled.

Four air cylinders are used, each operating an independent point. The air control is hand operated and so arranged that an initial air line supply pressure of 80 lb. will give from 300 to 700 lb. pressure between the points during the heating period. A second step on the air control makes it possible

to apply 1,200 lb. pressure between the points for the final squeeze. The air is exhausted into the reverse side of the cylinders to withdraw the points. The regulating transformer supplies power to the welding transformer in eight voltage steps.

FEDERAL AUTOMATIC SPOT-WELDER FOR CHANNELS

The machine shown in Fig. 255 was made for spot-welding two rolled steel channels together to form an I-beam. It is

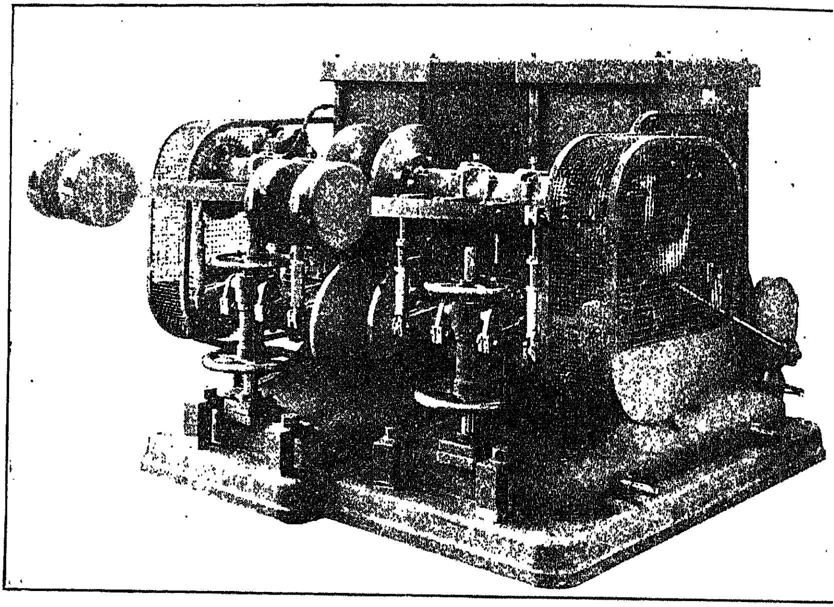


FIG. 255.—Federal Channel Welding Machine.

capable of welding two spots at a time on two pieces of material ¼ in. thick, at the rate of 60 welds per min. The two welding transformers are for 220 volts primary, and are air cooled. Four copper disks are used for welding contacts. These are securely bolted to bronze shafts to insure good electrical connections. The secondaries of the welding transformers are connected to the brass bearings of these shafts, completing the welding circuit.

The welding current is controlled by auto transformers

in the primary circuit in eight equal steps from 65 per cent to full line voltage.

The welding disks can be adjusted to handle from 4 to 16 in. channels. Simultaneous spot welds from 4 to 12 in. apart may be made. A variable speed motor is used to control the feeding of the work through the machine at from 25 to 60 ft. per min.

AUTOMATIC PULLEY WELDING MACHINE

The machine shown in Fig. 256 was made to weld the ring section of pressed-metal pulleys, known as the filler, to the

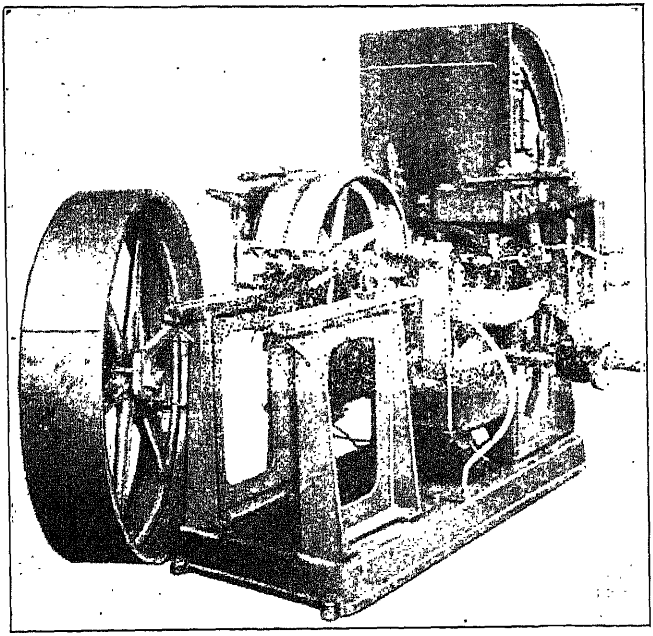


FIG. 256.—Automatic Electric Pulley Welder.

rim itself. This ring, or filler, not only acts as a stiffener for the rim, but is the part to which the outer ends of the spokes are attached.

In welding, one-half of a pulley rim is locked by means of a chain-clamping device to a rotating carrier, with the filler and spokes in place as shown. An adjustable mandrel on the

carrier insures the proper distance between the center of the pulley and the rim face. Duplicate welding sets operate on each side of the filler, and spot weld intermittently as the work is automatically indexed around.

The mechanical part of the machine is motor driven, and with the work in place, the machine will properly space and weld around the filler until it reaches the end, when it automatically trips. The points are water cooled and will make

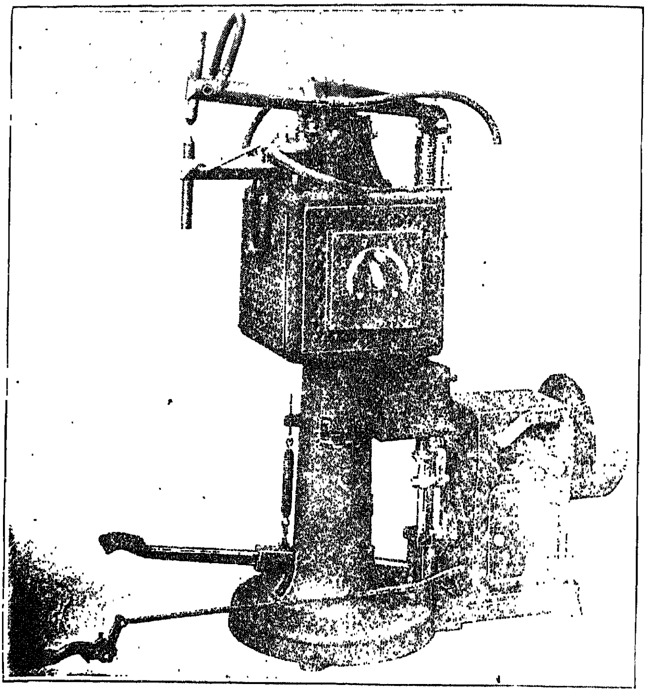


FIG. 257.—Taylor Cross-Current Spot-Welding Machine.

about 60 welds per minute. These welding points can be set to weld within $2\frac{1}{2}$ in. of the center of the mandrel or supporting shaft, and have a maximum distance adjustment of 12 in. between them. The automatic indexing or feeding device is so arranged that welds from $\frac{1}{2}$ to 3 in. or more apart may be made. Pulleys from 12 in. up to 5 ft. in diameter may be handled, all the necessary adjustments being easily and quickly made to accommodate the various sizes.

This machine occupies a floor space of about 30×66 in., weighs about 3,500 lb.

The Taylor Welding Machines.—While the machines made by the Taylor Welder Co., Warren, Ohio, differ radically from others on the market, in that they employ double electrodes and cross current, the forms of the machines are about the same as those previously shown. An automatic belt-driven machine of the lighter type, is shown in Fig. 257. It may

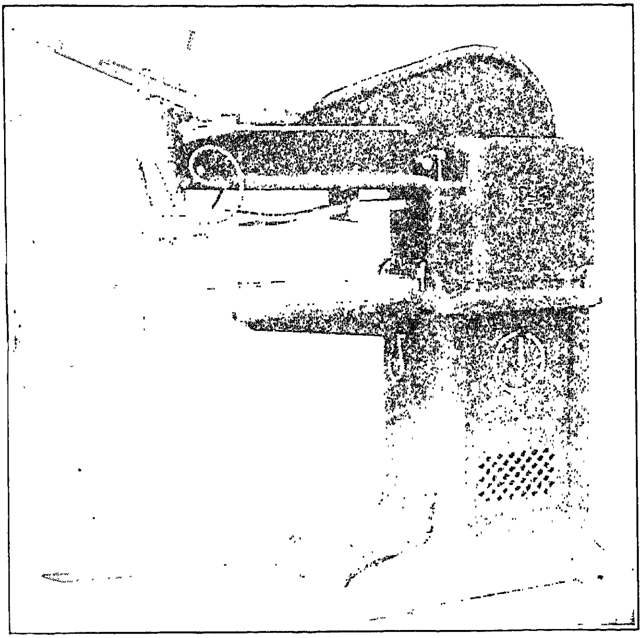


FIG. 258.—Taylor Heavy-Duty Machine.

be operated by the foot-treadle also when desired. This machine has a capacity up to two $\frac{1}{8}$-in. plates. The horns are water-cooled and the adjustable points are locked in with a wrench as shown. Fig. 258 shows a heavier type of machine. This has a capacity of two $\frac{1}{4}$-in. plates; overhang is 36 in.; distance between copper bands and lower horn, 6 in.; base, 26×42 in.; extreme height, 72 in.; greatest opening between welding points, 3 in.; weight about 2,400 lb. The transformer is 35 kw. and there is a ten-step self-contained regulator for

controlling the current. This firm makes other sizes and styles of machines, to meet all the demands of the trade.

The general principle of the cross-current welding method employed in these machines is illustrated in Fig. 259. Two separate currents are caused to flow in a bias direction through the material to be welded. A high heat concentration is claimed for this method. In operation, the positives of two separate

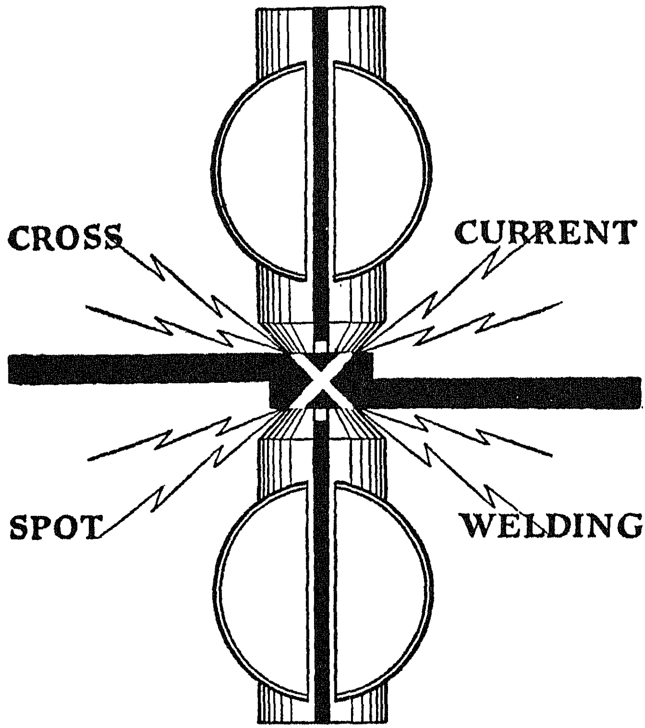


Fig. 259.—Diagram of the Current Action in a Taylor Machine.

welding currents are on one side of the material and the negatives on the other, with the co-working electrodes of each set so that the current travels diagonally across. An advantage claimed is that the electrodes on each side of the material may be set far enough apart to allow of the insertion of some hard material which will take the pressure instead of the softer copper welding points. These hard dies may be operated independently of the copper ones and make it possible to weld

heavier material without crushing the copper die points, as these need to be pressed together only enough to give good

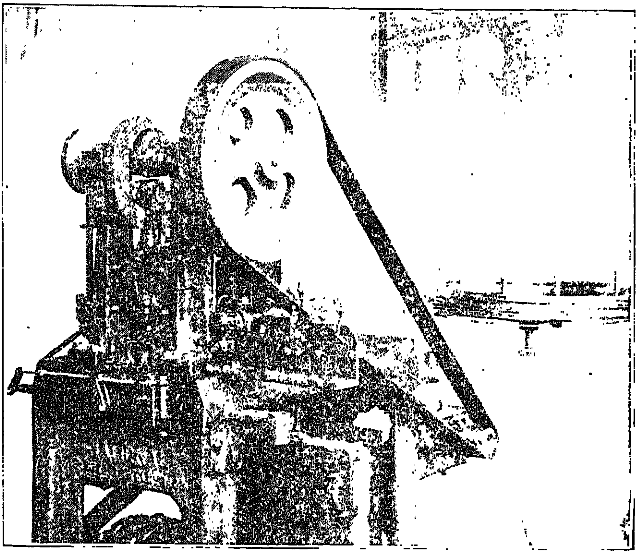


FIG. 260.—Automatic Hog-Ring Machine.

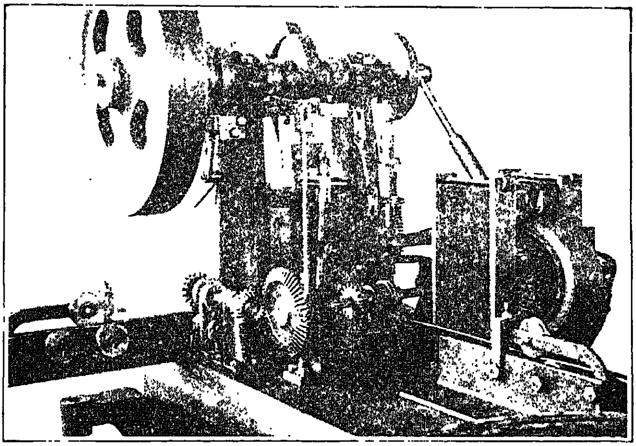


FIG. 261.—Partial Rear View of Hog-Ring Machine.

electrical contact with the work. The process is also unique in that it can be operated with a multiphase circuit without

unbalancing the lines, which is not the case with any spot-welding machine employing a single current.

Some Special Welding Machines.—An automatic machine for forming and mash-welding 11 gage wire hog rings, at the

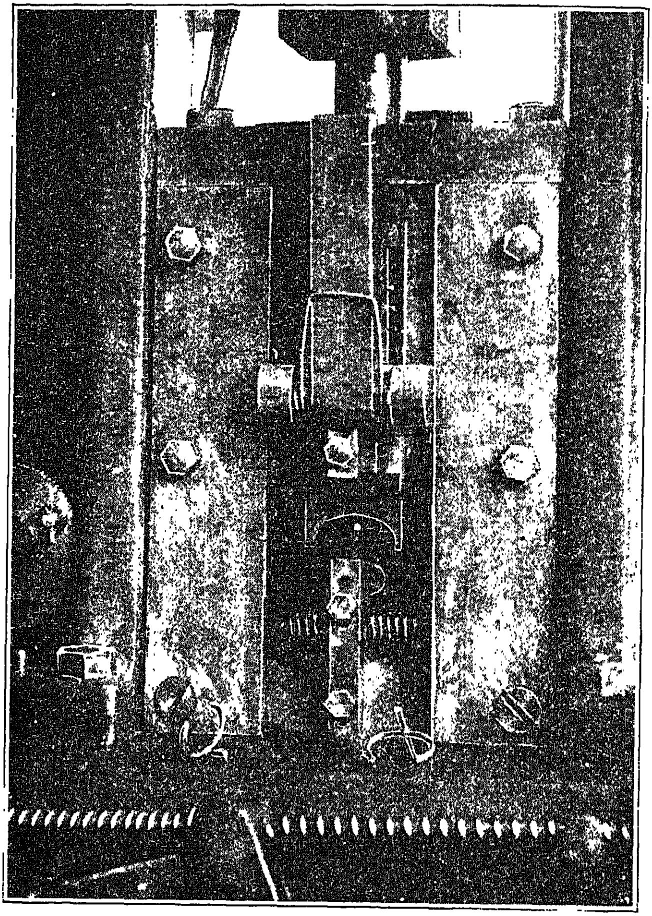


Fig. 262.—Close-Up of Front of Hog-Ring Machine.

rate of 60,000 per day, is shown in Fig. 260. This machine takes wire from two reels and turns out the complete hog rings. A partial rear view is shown in Fig. 261. A close-up of the front of the machine, with two hog rings lying on the platen, is given in Fig. 262.

A machine in use in the punch press department of the General Electric Co., Schenectady, N. Y., is shown in Fig. 263. This machine welds small spacers to the iron laminations for motors and generators for ventilating purposes, and hence is

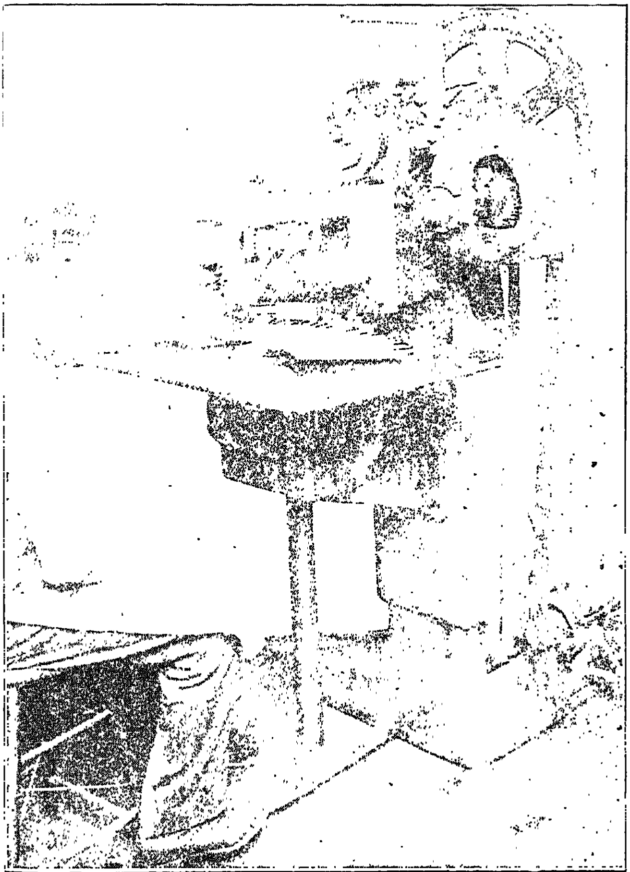


FIG. 263.—General Electric Space-Block Welding Machine.

called a "space-block welder." A number of these machines are in use in this plant, and they are capable of welding 60 spots per minute when working continuously, not allowing for time to shift the stock.

A combination spot- and line-welding machine, used in the

General Electric Co.'s shops, is shown in Fig. 264. This is employed for welding oil switch boxes up to $\frac{1}{8}$ in. thick. As shown, the machine is fitted with a fixture for holding the boxes while line-welding the seams. A separate fixture is put

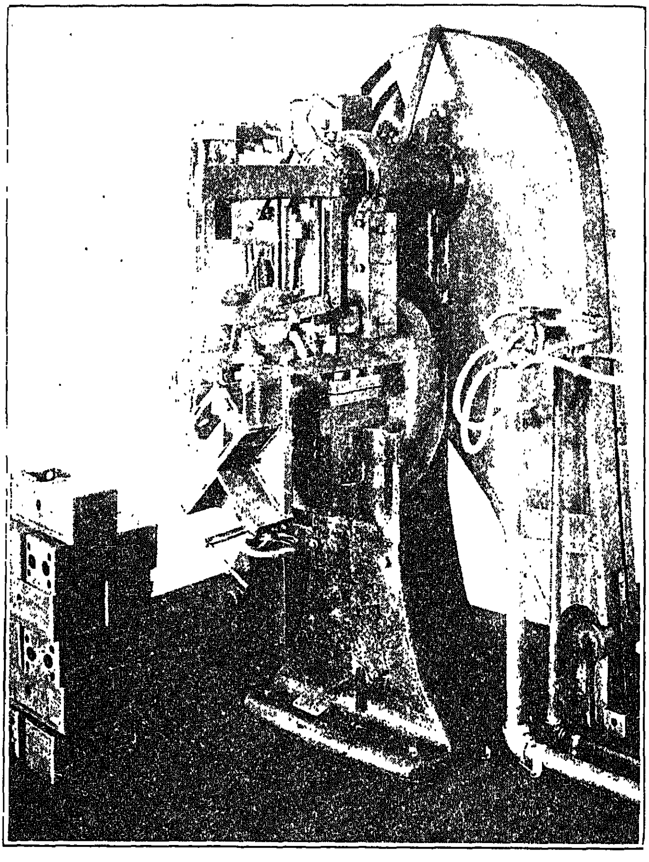


FIG. 264.—Combination Spot- and Line-Welding Machine, Set Up for Line-Welding Can Seams.

on for spot-welding work. A seam 6 in. long can be line-welded on this machine.

Another combination machine, used in the same shops, is shown in Fig. 265. This machine carries both the spot- and the line-welding fixtures at the same time. Fig. 266 shows the machine from the line-welding side. As shown, the

machines are ready for welding straight plates. Machines of this kind should find a considerable field where it is desired to tack seams before line welding them. These machines have

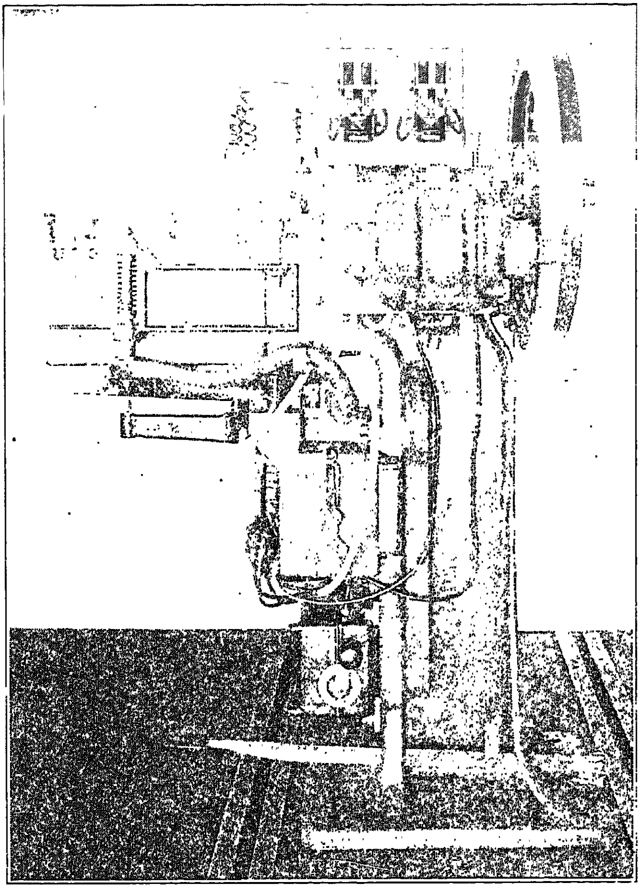


FIG. 265.—A Combination Machine from the Spot-Welding Side.

a capacity of 20 kva., and will weld up to $^3/_{16}$ in. thick, and seams 18 in. long.

Line welding machines, as developed in the Schenectady plant, comprise a transformer with a one turn secondary, through which a heavy current is delivered at low voltage to the material through the medium of a stationary jaw and roll-

ing wheel. Both the jaw and wheel are water-cooled and pressure is applied to the wheel the same as to a spot-welding tip. A small revolving switch mechanically geared to the driving motor and welding wheel operates a set of contactors

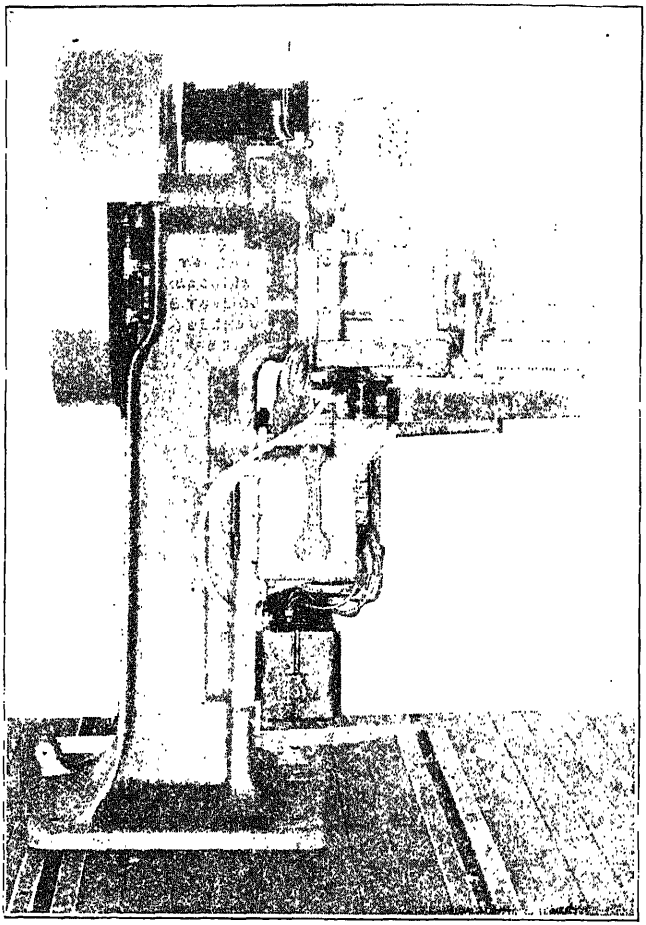


FIG. 266.—Machine from the Line-Welding Side.

or solenoid switches to throw the power on once a second, the power being on $\frac{3}{8}$ of a second, and off $\frac{5}{8}$ of a second. The mechanism is synchronized so that during the $\frac{3}{8}$ of a second the power is on, the welding wheel is rolling, and during the

remaining $\frac{5}{8}$ of a second the wheel is stationary under pressure while the soft metal is solidifying, thus completing the weld.

Spot-Welding Machines for Ship Work.—During the World War, welding of all kinds took huge steps forward. Spot-welding developed at least as much as any other kind. Writing in the *General Electrical Review*, J. M. Weed says:

The machines to be described are two portable welders, one with 12-in. reach and the other with 27-in. reach, for use in the fabrication of structural ship parts, and one stationary machine with 6-ft. reach designed for welding two spots at the same time on large ship plates.

A preliminary survey of the structural work in shipbuilding indicated that about 80 per cent of this work could be done by a machine of 12-in reach, and that a 27-in. reach would include the other 20 per cent. Since both the weight of the machine and the kva. required for its operation are about 33 per cent greater for the 27-in. reach than for the 12-in., it seemed advisable to develop two machines rather than one with the longer reach.

These machines were to a certain obvious extent patterned after the riveting machines, which they were intended to replace as will be seen from Fig. 267. They are necessarily considerably heavier than the riveting machines, but like these they are provided with bales for crane suspension, for the purpose of carrying the machines around the assembled work or parts to be welded.

The maximum welding current available in these machines, with a steel plate enclosed to the full deptn of the gap, is about 37,500 amperes, with the maximum applied voltage of 534 volts at 60 cycles. Reduced voltages, giving smaller currents, are obtained in six equal steps, ranging from 534 down to 267 volts, from the taps of the regulating transformers furnished with the machines.

This wide range of voltage and current was provided in order to meet the possible requirements for a considerable range in thickness of work, and for experimental purposes. Tests have shown, however, that the machines will operate satisfactorily on work of thicknesses over the range on which they are likely to be used when connected directly on a 440-volt, 60-cycle circuit, with no regulating transformers. Two plates $\frac{1}{2}$-in. thick are welded together in spots from 1 in. to $1\frac{1}{4}$ in. in diameter, in from 12 to 15 seconds. Thicker plates require more time and thinner plates less time.

The welding current under these conditions is about 31,000 amp.; the primary current is about 600 amp. for the 12-in. machine and about 800 amp. for the 27-in. machine, the corresponding kva. at 440 volts, being 265 and 350 respectively.

Since the reactance of the welding circuit is large as compared with the resistance, the voltage necessary for a given current, and consequently the kva. necessary for the operation of the machine, is almost proportional to the frequency. Thus, these machines operate satis-

factorily from a 25-cycle circuit at 220 volts, with the advantage that where the power-factor is from 30 to 40 per cent at 60 cycles, it is from 60 to 75 per cent at 25 cycles, and the kva. required at 25 cycles is about one-half that required at 60 cycles.

The maximum mechanical pressure on the work for which those machines are designed is 25,000 lb. This is obtained from an 8-in. air cylinder, with an air pressure of 100 lb. per square inch, acting through a lever arm of 5 to 1 ratio. Lower pressures on the work are obtained with

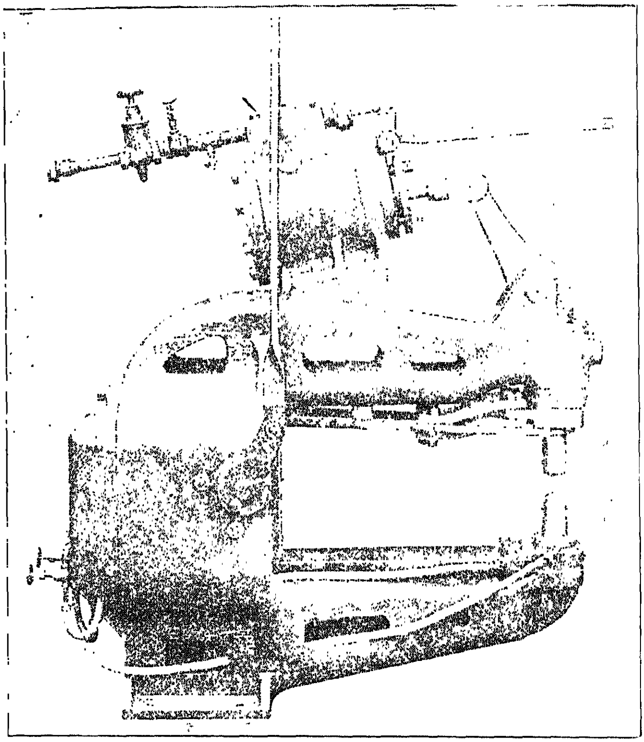


FIG. 267.—Portable Spot-Welding Machine with 27-in. Throat Depth. Capable of Welding Two Plates ⅝ In. Thick in Spots 1 In. in Diameter. Made by the General Electric Co.

correspondingly reduced air pressures. A pressure-reducing valve is provided for this purpose, and also a pressure gage for indicating the pressure on the machine side of the valve.

The pressure required to do satisfactory welding depends upon the thickness of the plates. It is necessary that the areas to be welded should at the start be brought into more intimate contact than the surrounding areas, in order that the current may be properly localized, and the heat

generated in the region where it is needed. It is therefore necessary, on account of irregularities in the plate surface, that the pressure should be great enough to spring the cold plate sufficiently to overcome the irregularities. The pressure which will do this with heavy plates is ample for effecting the weld after the welding temperature is reached.

It should be explained in this connection that the rate of heating at the surfaces to be welded depends largely upon the contact resistance, and consequently upon the condition of the plates and the pressure used. If the plates are clean and bright, and the pressure high, the rate of heating with a given amount of current is slow and the welding efficiency is poor. This makes it difficult to weld heavy plates if they are clean, since, as stated above, it is necessary to use large pressure with heavy plates to insure a better contact of the areas to be welded than that of surrounding areas. It is much easier to weld plates which carry the original coat of mill scale, or a fairly heavy coating of rust or dirt, affording a considerable resistance which is not sensitive to pressure. If this resistance is too great, the necessary current will not flow, of course, but if the scale is not too heavy it has little effect upon the current, the high reactance of the welding circuit giving it practically a constant current characteristic and making the rate of heating proportional to the resistance within certain limits. The scale melts at about the welding temperature of the steel, and is squeezed out by the high pressures used, permitting the clean surfaces of the steel to come together and effect a good weld.

A gage pressure of about 70 lb., giving 17,500 lb. pressure upon the work, has been found to give good results under these conditions in ½-in. plates.

Both the mechanical pressure and the current are transmitted to the work in these machines through heavy copper blocks or welding electrodes. The shape of the tips of these electrodes is that of a very flat truncated cone.

The severity of the conditions to which the tips of the electrodes are subjected will be understood when it is considered that the current density in the electrode material at this point is approximately 60,000 amp. per square inch, and that this material is in contact with the steel plates which are brought to the welding temperature, under pressures of 15,000 to 20,000 lb. per square inch. It must be remembered, also, that copper, which is the best material available for this purpose, softens at a temperature considerably lower than the welding temperature of steel. The difficulty of making the electrode tips stand up under the conditions to which they are subjected has, in fact, constituted the most serious problem which has been met in the development of these machines.

The shape of these electrodes gives them every possible advantage in freely conducting the current to and the heat away from the electrode tips, and in giving them the mechanical reinforcement of the cooler surrounding material. However, it has been found necessary to reduce, as far as possible, the heat generated at the tips of the electrodes by cleaning the rust and mill scale from the surfaces of the plates beneath the elec-

trodes. The most convenient way which has been found for doing this is by means of a sand blast. The bodies of the electrodes are also internally water-cooled by a stream of water flowing continually through them. Still after all of these things have been done, a gradual deformation of the tip of the electrode will occur, increasing its area of contact with the work and thus reducing the current density in the work and the pressure density below the values needed for welding. This would make it necessary to change electrodes and to reshape the tips very frequently, and the total life of the electrodes would be short on account of the frequent dressings.

An effort has been made to overcome this difficulty by protecting the tip of the electrode by a thin copper cap, which may be quickly and cheaply replaced. As many as 160 welds have been made with a single copper cap, $^1/_{16}$ in. thick, before it became necessary to replace it. Unfortunately this does not entirely prevent the deformation of the electrode tip, but it stands up much better than it does without the cap.

Another method which has been tried for overcoming this trouble is by making the tip portion of the electrode removable, in the form of a disk or button, held in place by a clamp engaging in a neck or groove on the electrode body. While this protects the electrode body from deformation and wear, the tip itself does not stand up so well as does the combination of electrode and cap, where the tip of the electrode is not separated from the body.

Some electrodes have been prepared which combine the features of the removable tip and cap. These give the advantage of a permanent electrode body, and the removable tip with the protecting cap stand up better than the unprotected tip.

Some interesting features were introduced in the design of the transformers which are integral parts of these machines, owing to the necessity for small size and weight. Internal water cooling was adopted for the windings, which makes it possible to use current densities very much higher than those found in ordinary power transformers. The conductor for the primary windings is $\frac{3}{8}$-in.$\times\frac{1}{2}$-in. copper tubing, which was obtained in standard lengths and annealed before winding by passing it through an oven which is used for annealing sheathed wire during the process of drawing. No difficulty was found in winding this tubing directly on the insulated core, the joints between lengths being made by brazing with silver solder. The entire winding consists of four layers of thirteen turns each in the 12-in. machine and three layers of thirteen turns each in the 27-in. machine.

The U-shaped single-turn secondaries were slipped over the outside of the primary windings in the assembly of the transformers. These were constructed of two copper plates each $\frac{3}{8}$ in. thick and $6\frac{3}{8}$ in. wide, which were bent to the proper shape in the blacksmith shop, and assembled one inside the other with a $\frac{1}{4}$-in. space between them. Narrow strips of copper were inserted between the plates along the edges, and the plates were brazed to these strips, thus making a water-tight chamber or passage for the circulation of the cooling water.

At 31,000 amp. the current density in these secondaries is about 6,200 amp. per square inch, the corresponding densities in the primary windings being about 7,000 for the 12-in. and 9,000 for the 27-in. machine.

In case these machines are started up without the cooling water having been turned on, the temperature rise in these windings will be rapid, and in order to avoid the danger of burning the insulation, asbestos and mica have been used. The copper tubing was taped with asbestos tape, and alternate layers of sheet asbestos and mica pads were used between layers of the primary winding, and between primary and secondary and between primary and core. Space blocks of asbestos lumber, which is a compound of asbestos and Portland cement, were used at the ends of the core and at the ends of the winding layers. The complete transformer, after assembly, was impregnated with bakelite. The result is a solid mechanical unit which will not be injured by temperatures not exceeding 150 deg. C. Several welds could be made without turning on the cooling water before this temperature would be reached.

The transformers are mounted on a chamber in the body of the frame. The long end of the U-shaped secondary runs out along the arm of the frame and bolts directly to the copper base upon which the bottom electrode is mounted. The short end connects to the base of the top electrode through flexible leads of laminated copper, to permit of necessary motion for engaging the work.

The copper bases upon which the electrodes are mounted are insulated from the frame by a layer of mica, the bolts which hold them in place being also insulated by mica.

The cooling water for these machines is divided into two parallel paths, one being through the primary winding, and the other through the secondary and the electrodes in series. Separate valves are supplied for independent adjustment of the flow in the two paths. The resistance of ordinary hydrant water is sufficiently great as to cause no concern regarding the grounding or short-circuiting of the windings through the cooling water, although it is necessary to use rubber tubing or hose for leading it in and out.

Some pieces of $\frac{1}{2}\times 2$-in. machine steel were welded in seven seconds with a current of 33,000 amp. They were afterward clamped in a vise and hammered into U-shapes. Small pieces were sheared from the seam where two $\frac{1}{2}$-in. plates had been welded together in a row of spots. The pieces of the plates were then split apart with a cold chisel in one case, and an effort was made to do so in the other, with the result that one piece of plate broke at the welds before the welds would themselves break. Such tests as these show that the welds are at least as strong as the material on which the welds were made. Some samples of the $\frac{1}{2}\times 2$-in. stock welded together in the same manner were tested by bending in an edgewise direction, thus subjecting the welds to a shearing torque. The ultimate strength calculated from these tests was in the neighborhood of 65,000 lb. per square inch. These tests showed also a very tough weld, the deflection being almost 45 deg. in some cases before the final rupture occurred. The maximum load occurred with a deflection of from 3 to 5

deg. with a very gradual reduction in the load from this time till the final rupture.

The Duplex Welding Machine.—The machine shown in Fig. 268 was developed for the application of electric welding as a substitute for riveting on parts of the ship composed of large-sized plates, which may be fabricated before they are assembled in the ship. The specification to which it was built stated that it should have a 6-ft. reach and should be capable of welding together two plates $\frac{3}{4}$ in. thick in two spots at the same time. A machine capable of doing this work, with a 6-ft. gap, is necessarily

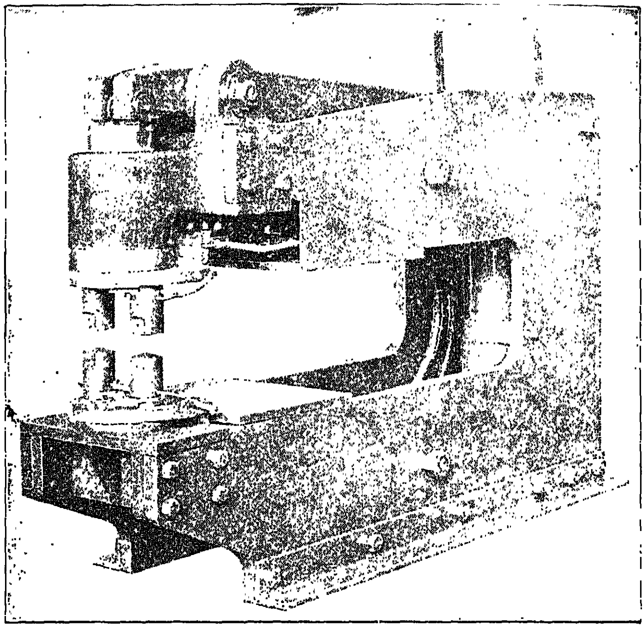


FIG. 268.—Duplex Spot-Welding Machine. Made by the General Electric Co. 6-ft. Throat Depth, and Capable of Welding Together Two Steel Plates $\frac{3}{4}$ In. Thick, in Two Spots $1\frac{1}{4}$ In. in Diameter.

so heavy as to preclude even semi-portability, and no effort was made in this direction.

With the welding circuit enclosing a 6-ft. gap, and carrying the very heavy current necessary to weld $\frac{3}{4}$-in. plates, the kva. required would be very large. A great reduction in the kva. and at the same time a doubling of the work done, is obtained in this machine by the use of two transformers as integral parts of the machine, and two pairs of electrodes, thus providing for the welding of two spots at the same time. The transformers are mounted in the frame of the machine, on opposite sides of the work, and as near to the welding electrodes as possible, so as to

obtain the minimum reactance in the welding circuit. The polarity of the electrodes on one side of the work is the reverse of that of the opposed electrodes, thus giving a series arrangement of the transformer secondaries, the current from each transformer flowing through both of the spots to be welded.

The bottom electrodes are stationary, and the copper bases which bear them are connected rigidly to the terminals of their transformer, while the bases which carry the top electrodes are connected through flexible leads of laminated copper, to permit of the motion necessary for engaging the work.

Previous tests with an experimental machine had shown that, to successfully weld two spots at the same time in the manner adopted here, it is necessary that the pressures shall be independently applied. Otherwise, due to inequalities in the thickness of the work, or in the wear and tear of the electrodes, the pressure may be much greater on one of the spots than on the other. This results in unequal heating in the two spots. The resistance and its heating effect are less in the spot with the greater pressure. The two top electrodes in this machine were therefore mounted on separate plungers, operated by separate pistons through independent levers.

The pressures obtained in this machine with an air pressure of 100 lb. per square inch, are 30,000 lb. on each spot, giving a total pressure of 60,000 lb. which must be exerted by the frame around the 6-ft. gap. The necessary strength is obtained by constructing the frame of two steel plates, each 2 in. thick, properly spaced and rigidly bolted together.

The use of steel in this case is easily permissible on account of the restricted area of the welding circuit and its relative position, resulting in small tendency for magnetic flux to enter the frame. However, the heads carrying the electrodes, being in close proximity to the welding circuit, were made of gun metal.

The two air cylinders are mounted on a cast-iron bed-plate in the back part of the machine. The levers connecting the pistons to the electrode plungers, which are 7 ft. in length, were made of cast steel, in order to obtain the necessary strength.

The maximum welding current for which this machine was designed is 50,000 amp. This current is obtained with 500 volts at 60 cycles applied.

The distance between the electrode bodies for this machine is fixed at 8 in., center to center, but the distances between the centers of the tips may be easily varied from 6 in. to 10 in. by shifting the tip from the center of the body toward one side or the other.

Provision has been made for shifting the electrodes on their bases to positions 90 deg. from those shown in the picture, thus spacing the welds in a direction along the axis of the machine instead of traverse to it.

The transformers are insulated and cooled in the same manner as those in the semi-portable machines. The windings are interlaced in order to obtain minimum reactance, the primary being wound in two layers of 14 turns each, one inside and the other outside of the single turn secondary.

With 50,000 amp. in the secondaries of these transformers, the current

in the primary is 1,800. The respective current densities are 7,000 a
9,000 amp. per square inch. The kva. entering the transformers on tl
basis, the two primaries being in series on 500 volts, is 450 for ea
transformer.

This machine also has been provided with a regulating transform
for applying different voltages to give different values of welding curre

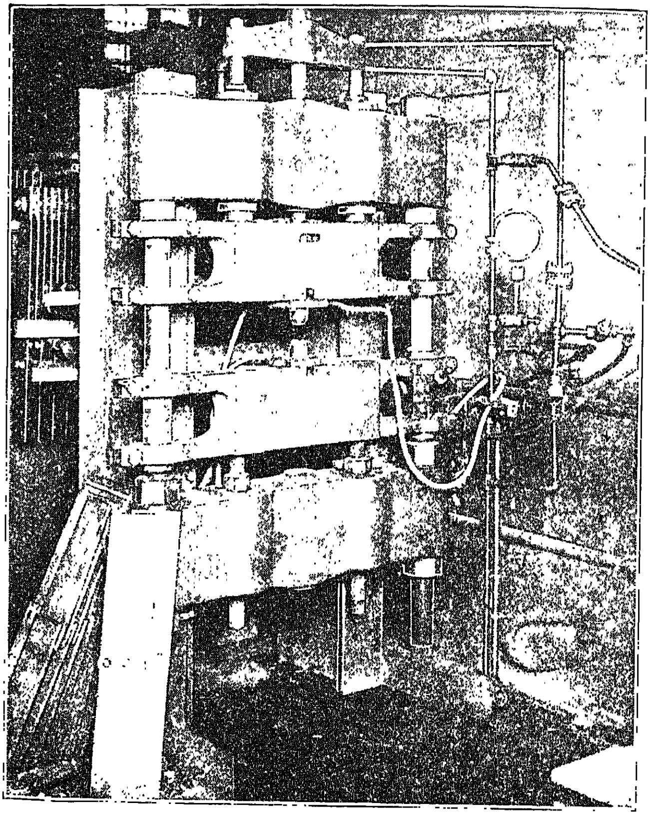


FIG. 269.—General Electric Co.'s Experimental Spot-Welding Machine Current Capacity 100,000 Amp. Pressure Capacity 36 Tons. Has Welded Three Plates, Each 1 In. Thick.

and with a panel carrying the necessary selector switches and contactor The maximum voltage provided by this regulating transformer as at present constructed is 440. If it is found that the current obtained with this voltage is not sufficient for the heaviest work which it is desired to do with this machine, the maximum voltage may be changed to 500.

The kva. entering the transformers of 440 volts will be approximately 350 each, instead of 450.

In order that this machine may be operated from any ordinary power circuit, it will be necessary to use a motor-generator set provided with a suitable flywheel. This will eliminate the bad power-factor, distribute the load equally on the three phases, and over a much larger interval of time for each weld, thus substituting small gradual changes in power for large and sudden changes. On account of the high reactance the welding current will remain practically constant as the speed of the motor-generator set falls away, thus favoring the utilization of the flywheel. The total maximum power drawn from the circuit with this arrangement would be about 100 kilowatts.

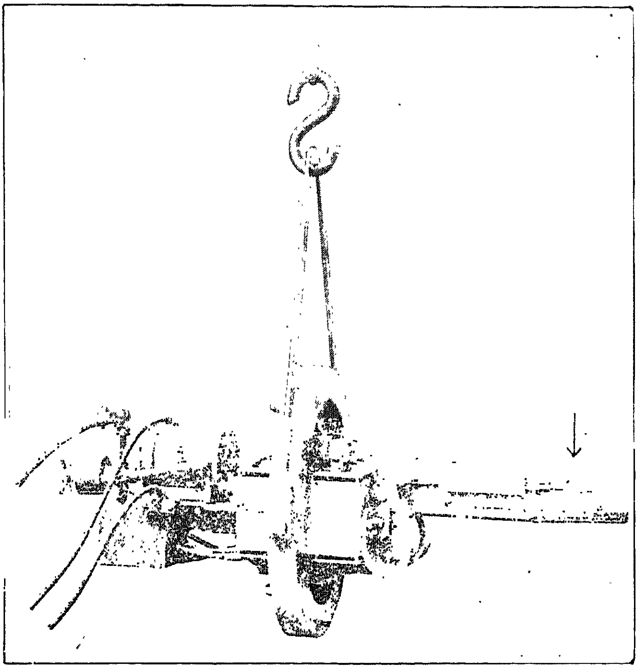


FIG. 270.—Portable Machine for Mash-Welding Square or Round Rods.

A Heavy Experimental Spot-Welding Machine. — The machine shown in Fig. 269 was built in 1918 by the General Electric Co., in order to investigate the possibilities of welding plates from $\frac{1}{4}$ in. up. Three plates each 1 in. thick have been welded with it. The machine is provided with a 2,000-kva. transformer, having a capacity of 100,000 amp. at 20 volts. Hydraulic pressures up to 36 tons are obtained at the electrodes. Motor-generator sets of 500- and 6,000-kva. capacity

were used. From the nature of the service, it was appar
that some form of cooling was needed at the contact poir
It was found, however, that it was impossible to water-c
the points sufficiently to give a reasonable life to the electro
if they were kept the same diameter for any distance fr
the work. In consequence heavy masses of copper were plac

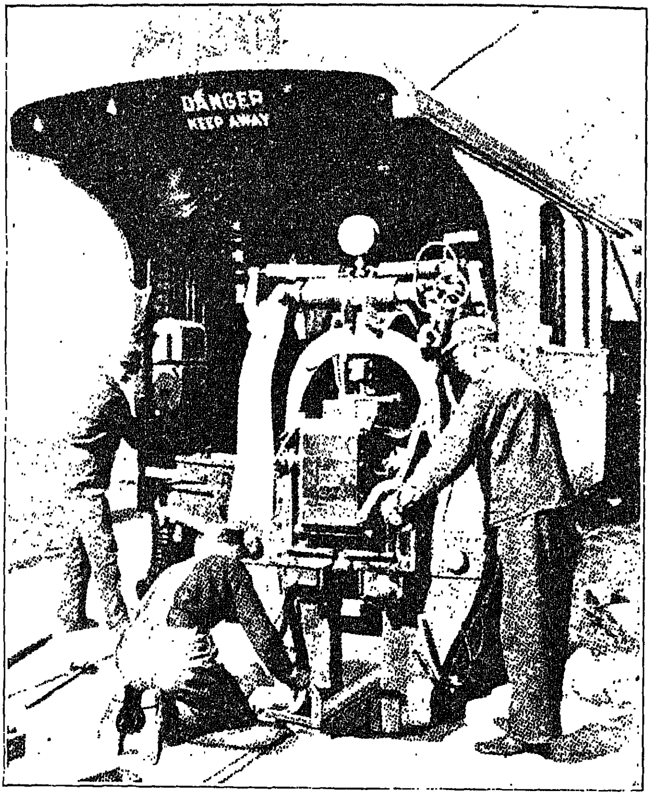


Fig. 271.—Lorain Machine for Spot-Welding Electric Rail Bonds.

as close to the points of contact as practicable. By doing this
it was possible to have a very large cooling surface at the
top of the electrode and by passing water through this part
at the time of welding and between welds, the joints were kept
cool enough for all practical purposes.

A portable machine for making mash-welds for splicing or
attaching round or square rods cross-wise, is shown in Fig.

270. This was made by the General Electric Co., for shipyard use.

A big machine for spot-welding electric railway bonds, is shown in Fig. 271. This is made by the Lorain Steel Co., Johnstown, Pa. It will weld two plates 18 in. long and 3 in. wide by 1 in. thick, each plate having three raised "welding bosses." Pressure as high as 35 tons is obtainable and current up to 25,000 amp. may be used.

Spot-Welding Data.—It is difficult to give definite costs for spot welding, as much depends on the operator. A careless or inexperienced operator will waste more current than a good one, and various conditions of the metal being worked on will make a considerable difference at times. However, the information given in Table XXIII, which is furnished by the Winfield Electric Welding Machine Co., will prove of value as a basis for calculations. Tables XXIV and XXV will also be useful to use in connection with the measurement of the thickness of sheets, and in comparing different gages.

TABLE XXIII.—SPOT-WELDING POWER AND COST DATA

Gauge Number	Thickness of Sheets in Fractions of an Inch	Thickness of Sheets in Decimals of an Inch	K. W. Required	H. P. Required	Time in Seconds to Make a Weld	Cost 1000 Welds at one Cent per K. W. Hour
30	1/80	.0125	3.0	4.2	.25	.002
28	1/64	.0156	4.0	5.6	.3	.003
24	1/40	.0250	5.0	7.0	.45	.006
20	3/80	.0375	6.5	9.2	.6	.011
18	1/20	.0500	8.0	11.3	.8	.017
16	1/16	.0626	9.5	13.5	1.0	.026
14	5/64	.0781	10.0	14.2	1.3	.036
12	7/64	.1093	12.0	17.0	1.6	.052
11	1/8	.1250	13.0	18.5	1.7	.061
10	9/64	.1406	14.0	19.9	1.8	.070
9	5/32	.1562	15.0	21.3	1.9	.079
8	11/64	.1715	16.0	22.7	2.0	.088
7	3/16	.1875	17.0	24.1	2.1	.099
6	13/64	.2031	18.0	25.6	2.2	.110
5	7/32	.2187	19.0	27.0	2.4	.124
4	15/64	.2343	20.0	28.4	2.7	.148
3	1/4	.2500	21.0	29.8	3.0	.174

As the cost of current varies in different places, we have figured the current at one cent per K. W. hour to give a basis for calculating the cost. Multiply the cost of current given above by the rate per K. W. hour you pay and you will have your cost per 1000 welds for current.

TABLE XXIV.—THICKNESS AND WEIGHT OF SHEET IRON AND STEEL, U. S. STANDARD.

Number of Gauge	Approximate Thickness in Fractions of an Inch	Approximate Thickness in Decimal Parts of an Inch	Weight per Sq. Foot Iron	Number of Gauge	Approximate Thickness in Fractions of an Inch	Approximate Thickness in Decimal Parts of an Inch	Weight per Sq. Foot Iron
30	1-80	.0125	.5	13	3-32	.09375	3.75
29	9-640	.0140625	.5625	12	7-64	.109375	4.375
28	1-64	.015625	.625	11	1-8	.125	5.
27	11-640	.0171875	.6875	10	9-64	.140625	5.625
26	3-160	.01875	.75	9	5-32	.15625	6.25
25	7-320	.021875	.875	8	11-64	.171875	6.875
24	1-40	.025	1.	7	3-16	.1875	7.5
23	9-320	.028125	1.125	6	13-64	.203125	8.125
22	1-32	.03125	1.25	5	7-32	.21875	8.75
21	11-320	.034375	1.375	4	15-64	.234375	9.375
20	3-80	.0375	1.50	3	1-4	.25	10.
19	7-160	.04375	1.75	2	17-64	.265625	10.625
18	1-20	.05	2.	1	9-32	.28125	11.25
17	9-160	.05625	2.25	0	5-16	.3125	12.50
16	1-16	.0625	2.5	00	11-32	.34375	13.75
15	9-128	.0703125	2.8125	000	3-8	.375	15.
14	5-64	.078125	3.125				

TABLE XXV.—DECIMAL EQUIVALENTS OF AN INCH FOR MILLIMETERS, B. & S. AND BIRMINGHAM WIRE GAGES

Decimal Inch	Mill.	Fra. In.	B&S	Birm Gge.	Decimal Inch	Mill.	Fra. In.	B&S	Birm. Gge.	Decimal Inch	Mill.	Fra. In.	B&S	Birm Gge.
.00394	.1				.11443			9		.296875		19/64		
.00787	.2				.11811	3.0				.29921	7.6			
.010025			30		.12				11	.3				1
.011257			29		.12204	3.1				.30314	7.7			
.01181	.3				.125		1/8			.30708	7.8			
.012				30	.12598	3.2				.31102	7.9			
.012641			28		.12849			8		.3125		5/16		
.013				29	.12992	3.3				.31496	8.0			
.014				28	.13385	3.4				.31889	8.1			
.014195			27		.134				10	.32283	8.2			
.015625		1/64			.13779	3.5				.32495			0	
.01575	.4				.140625		9/64			.32677	8.3			
.01594			26		.14173	3.6				.328125		21/64		
.016				27	.14428			7		.3307	8.4			
.0179			25		.14566	3.7				.33464	8.5			
.018				26	.148				9	.33858	8.6			
.01968	.5				.14960	3.8				.34				0
.02				25	.15354	3.9				.34251	8.7			
.0201			24		.15625		5/32			.34375		11/32		
.022				24	.15748	4.0				.34645	8 8			
.022571			23		.16141	4.1				.35039	8 9			
.02362	.6				.16202			6		.35433	9.0			
.025				23	.165				8	.35826	9.1			
.025347			22		.16535	4.2				.359375		23/64		
.02756	.7				.16929	4.3				.36220	9.2			
.028				22	.171875		11/64			.3648				00
.02846			21		.17322	4.4				.36614	9.3			
.03125		1/32			.17716	4.5				.37007	9.4			
.03149	.8				.180				7	.37401	9.5			
.03196			20		.1811	4.6				.375		3/8		
.032				21	.18194			5		.37795	9.6			
.035				20	.18503	4.7				.38				00
.03543	.9				.1875		3/16			.38188	9.7			
.03589			19		.18897	4.8				.38582	9.8			
.03937	1.0				.19291	4 9				.38976	9 9			
.04030			18		.19685	5.0				.390625		25/64		
.042				19	.20078	5.1				.3937	10 0			
.0433	1.1				.203				6	.39763	10 1			
.04525			17		.203125		13/64			.40157	10.2			
.46875		3/64			.20431			4		.40551	10.3			
.04724	1.2				.20472	5.2				.40625		13/32		
.049				18	20866	5.3				.40499	10.4			
.05082			16		.21259	5.4				.4096			000	
.05118	1.3				.21653	5.5				.41338	10.5			
.05512	1.4				.21875		7/32			41732	10.6			
.05706			15		.22				5	.42125	10.7			
.058				17	.22047	5.6				.421875		27/64		
.05905	1.5				.2244	5.7				.425				000
.0625		1/16			.22834	5.8				.42519	10.8			
.06299	1.6				.22942			3		.42913	10.9			
.06408			14		.23228	5.9				.43307	11.0			
.065				16	.234375		15/64			.437	11.1			
.06692	1.7				.23622	6.0				.4375		7/16		
.07086	1.8				.238				4	.44094	11.2			
.07196			13		.24015	6.1				.44488	11.3			
.072				15	.24409	6.2				.44881	11.4			
.0748	1.9				.24803	6.3				.45275	11.5			
.078125		5/64			.25		1/4			.453125		29/64		
.07874	2.0				.25196	6.4				.454				0000
.080801			12		.2559	6.5				.45669	11.6			
.08267	2.1				.25763			2		.46			0000	
.083				14	.259				3	.46062	11.7			
.08661	2.2				.25984	6.6				.46456	11.8			
.09055	2.3				.26377	6.7				.4685	11.9			
.09074			11		.265625		17/64			.46875		15/32		
.09375		3/32			.26771	6.8				.47244	12.0			
.09448	2.4				.27165	6.9				.47637	12.1			
.095				13	.27559	7.0				.48031	12.2			
.09842	2.5				.27952	7.1				.48425	12.3			
.10189			10		.28125		9/32			.484375		31/64		
.10236	2.6				.28346	7.2				.48818	12.4			
.10629	2.7				.284				2	.49212	12.5			
.109				12	.2874	7.3				.49606	12.6			
.109375		7/64			.2893			1		.49999	12.7			
.11023	2.8				.29133	7.4				.5		1/2		
.11417	2.9				.29527	7.5				.50393	12.8			

CHAPTER XIV

WELDING BOILER TUBES BY THE ELECTRIC RESISTANCE PROCESS

About 1912 the resistance, or Thomson, process of elec welding was first tried out in a locomotive shop for the purp of replacing the oil-furnace welding equipment in safe-end boiler tubes up to 2½ in. in diameter, says P. T. Van Bibl in the *American Machinist.* At the present time, in shops different parts of the country where electric welding machi have been installed, one will find many enthusiastic "booste for this process. It is to these users that we are indebted the information contained in this article and for the ben of those who are unfamiliar with this adaptation of resista welding, an endeavor has been made to cover all the det possible.

In using the resistance type of machine for welding sa ends onto locomotive-boiler flues, the old tube and the n safe-end are gripped securely in heavy copper jaws with ends to be joined held in alignment. As these ends pressed together a large volume of current from the second winding of the transformer is passed through them. Since junction of the abutting ends is the point of greatest resista to the electric current, the greatest heating effect is th and, usually, on a 2½-in. tube it requires only about 15 s to secure a perfect running or welding heat. A slight push- by the pressure device on the welding machine sticks the t parts together solidly enough so that the tube can be remov to the mandrel of a rolling machine, exactly as is done wh welding by the oil-furnace method, and the weld is then co pleted in a few seconds by rolling down the joint.

Since it is always necessary to scarf the ends of a tu and new safe-end before welding by the oil-furna method, the first question that the practical boiler-shop m

will ask is, How much preparation is needed for electric resistance welding? The first step in any method is to clear the tube from heavy scale, if in use under bad water conditions, by rolling in a large tumbling barrel. After this, the tubes are cut to the desired length to remove the old end that is to be replaced by the new section.

In some shops it is the practice to never allow more than one or two welds in a tube, which means that after removing the second time, the tube must be used in a shorter boiler than before. This procedure is carried out until the tube can only

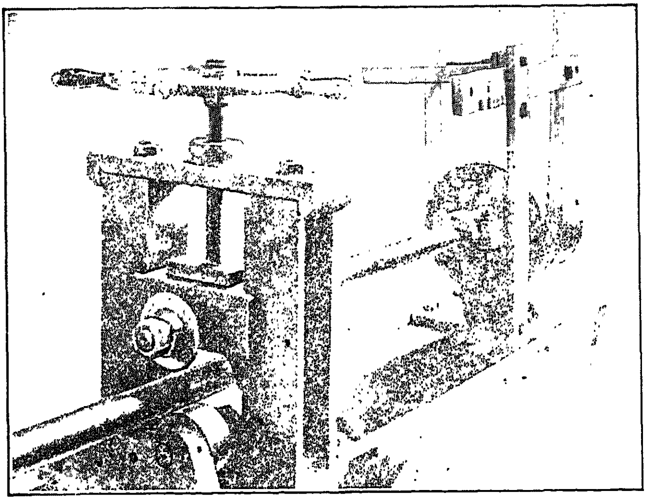


FIG. 272.—Machine for Cutting Off Flues.

be used for small switching locomotives—if it lasts that long—after which it is scrapped. By this method, only one length of tube is bought new, which is that required for the longest boilers.

In other shops the writer found tubes with many welds, showing that the safe-ending was continued in order to maintain the same length each time until the tube was worn out, when it was replaced by a new one of the required length. This latter method necessitates buying several lengths new but in localities where the water is not very hard on tubes, it prevents a tube from going to the scrap pile as long as there

is any good in it. After cutting off the old tubes, as shown in Fig. 272, which represents a common type of machine for this purpose, the tubes are next scarfed, or cut off square according to which method of welding is to be employed.

If a scarf weld is to be used, the old tube is generally

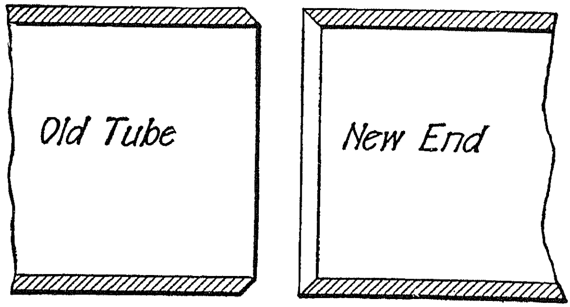


FIG. 273.—Ends Prepared for Scarf-Weld.

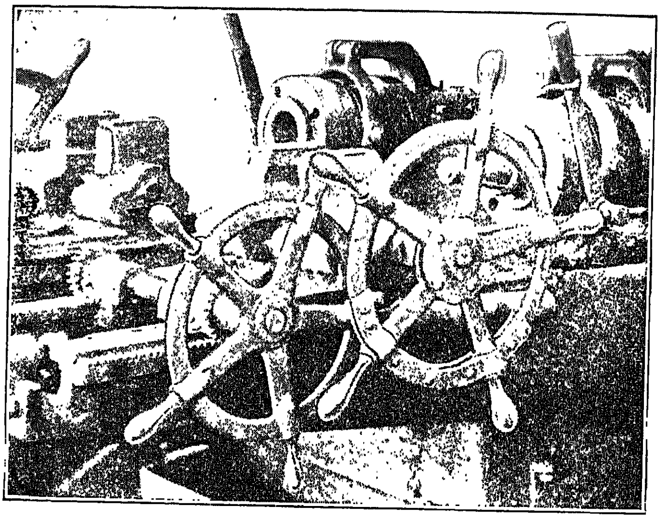


FIG. 274.—Bolt Threading Machine Made Into a Scarfing Machine.

beveled on the outside at an angle of from 45 to 60 deg., according to the length of scarf desired, about as shown in Fig. 273. The bevel is wholly a matter of personal opinion for just as good welds can be made with a 30-deg. scarf as when one of 60 deg. is used.

One type of machine used for scarfing is shown in Fig. 274. This has been rigged up from an old bolt-threading machine. The jaws shown at the left are for gripping the old tube which is then fed into a revolving chuck by means of the handwheel. This chuck contains the necessary cutters for forming the desired bevel on the outside of the tube end. The jaws on the right-hand side of the same machine grip the new short ends as they are fed onto a revolving tapered reamer, which cuts a scarf from the inside. In some shops, the scarfing is done on an old lathe with special fixtures, but the remodeled bolt-threading machine seems to offer the most efficient proposition for, with this type of machine, it is possible for one man to scarf over 60 tubes and ends per hour.

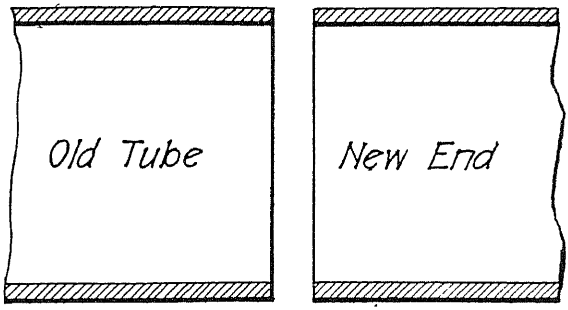


FIG. 275.—Ends Prepared for a Straight Butt-Weld.

If a straight butt-weld is to be made instead of scarfing the ends to be joined, they are cut off squarely, as shown in Fig. 275. This is done in an old pipe-threading machine, or a lathe, so that when placed in the welding machine, the abutting ends will be in contact practically all the way around their circumference. Although this last method of preparing work may sound shorter than scarfing, nevertheless, from actual observation of both methods in different shops, the former is faster by nearly two to one.

After preparing the ends for welding, if the tubes have not already been tumbled to remove all scale, which usually leaves the outside surface quite bright and clean, it is necessary to grind the surface of both old tube and new ends back to a distance of about 8 in. in order to secure a good electrical

contact between the tube metal and the copper jaws of tl welding machine.

There are three distinct methods of welding boiler tube which are called butt-, scarf- and flash-welding, the latt producing the same effect as a scarfed joint when complete In the straight butt-weld, the ends to be joined are first brough firmly together by means of the pressure device on the weldin machine, and the current is then turned on. There is alway some point around the circumference of the tube which start to heat first, due to the impossibility of making the two end to abut with the same pressure at all points of their contactin surfaces. However, the heat will gradually become uniforn all around the circumference before the welding temperatur is reached. The current is maintained through the tubes unti the joint reaches a good running heat, as evidenced by "greasy" appearance of the surface, when the pressure i applied sufficiently to push up the hot metal about $\frac{1}{8}$ in. whicl partly completes the weld. The jaws are then released and the tube is immediately thrust onto the mandrel of the rolling apparatus, which is described further on, and the bulge at the joint, caused by the pushing up of the hot metal, is rolled down until the joint is of the same diameter as the original tube.

This rolling-down operation, in addition to reducing this bulge of the tube, also forces a complete union of the plastic metal of the two pieces, thereby completing the weld. From this it may be seen that in welding boiler tubes, the welding machine is only used for a heating device to supplant the oil furnace, requiring only sufficient pressure to stick the ends together to hold it while removing work to the rolling machine where the welding is finished.

In the scarf weld, the beveled end of the old tube is pushed into the chamfered end of the new piece and the current then turned on the same as in making the butt-weld just described. Due to the "feather" edge of the short new piece, it is often necessary to apply the current intermittently until the joint is well heated all around the circumference; otherwise points of the sharp edge, which come in contact first with the opposite member, will be burned off before the heat is evenly distributed around the tube. Owing to the expanding effect of the scarfed

ends, it is not necessary to apply so much pressure as with the butt-weld when the metal is plastic in order to stick the pieces together before rolling down.

With either of the above welds, it is necessary to give the old tube more projection beyond the copper clamping jaws than is given the new short piece. This is because the wall thickness of the old tube has been slightly reduced by wearing away in service and if the two parts were given the same projection, the end of old tube would heat much more rapidly than that of the new piece since its resistance to the electric current would be greater, owing to the reduced sectional area. It is always necessary for the heat to form uniformly in each

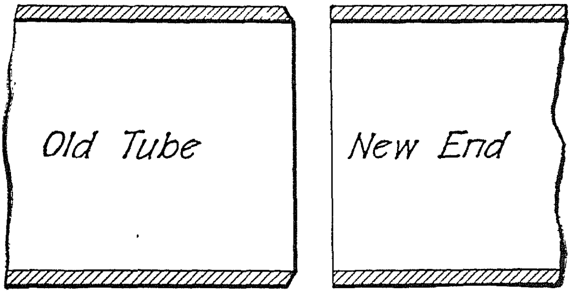


FIG. 276.—Ends Prepared for a Flash-Weld.

of the abutting ends or one will burn away before the other reaches the plastic stage.

In making a flash-weld, not so much preparation is required as for the two other methods just described; hence it is a much cheaper job and yet, from all tests made so far, it is the only type of joint which is always 100 per cent perfect when considering the number of defective welds in any lot of tubes. The old tube is cut off the right length in a machine, which has a cutting wheel so beveled as to give an angle of 30 deg. from the vertical on the end of the tube, as shown in Fig. 276. The new ends are bought direct from the tube manufacturers with both ends cut square and the surface cleaned well so that there is no preparation needed on the new pieces. After cutting off the old tube it is only necessary to grind it on the outside about 8 in. back from the end to insure good electrical contact. The old tube is placed in the

clamps with about 4 in. of projection and the new end wit about 3 in. The current is turned on first and the pressur is then applied very slowly and steadily to bring the abuttin ends into contact. As soon as they meet, a small arc or "flash is formed which commences to burn away the points of meta coming into contact first. This flashing is continued until th abutting ends are arcing all the way around the circumferenc and by this time the sharp edge of the old tube, althoug somewhat burned away itself, has burned its way into th square-cut end of the new piece. A sudden application of mor pressure stops the flashing and the joint then quickly attain the running or welding heat as in the butt- or scarf-weldin method. The ends are now shoved together and as the curren is turned off, the end of the old tube will have forced itsel into the end of the new piece sufficiently to form a scarf-weld when rolled down in the rolling machine.

Using a Flux.—From statements made by every operato interviewed, the use of flux does not help the welding in any way; yet it is used in each shop because it clears up the surface of the metal when the plastic stage is reached and enables the operator to judge the appearance of the heat more easily. The writer is confident that if a new operator were to be broken in on a welding machine, he would soon be able to correctly judge the right welding heat of the metal by its appearance without any flux, as there are many pipe shops using electric-welding machines for making joints in long coils, where flux was never heard of. Each railroad shop uses a slightly different kind of flux, but generally this material is nothing more than a common yellow clay, streaked with quartz formation, which has been pulverized and thoroughly dried out before using.

There are several methods and machines employed in the various shops for rolling down and completing the weld after heating the joint properly. One of the simplest machines in use is shown in Fig. 277. It consists of a power-driven mandrel slightly smaller than the internal tube diameter, above which is a power-driven roller. This roller is held a short distance above the mandrel by a spring. When the hot tube is thrust onto the mandrel, the upper roller is brought firmly down onto the outside surface of the joint by pressure on a foot treadle

located under the table on which the device is mounted. The pressure is maintained until the joint has been rolled down to outer tube size. The main disadvantage of this style of apparatus is that the speeds of the roller and the mandrel must be in the correct ratio so as to not allow any slip on either inner or outer surface of the tube, otherwise the tube will roll unevenly and when finished will have a thicker wall on one side than on the other. However, this is the earliest form of rolling machine used with the electric-welding method and

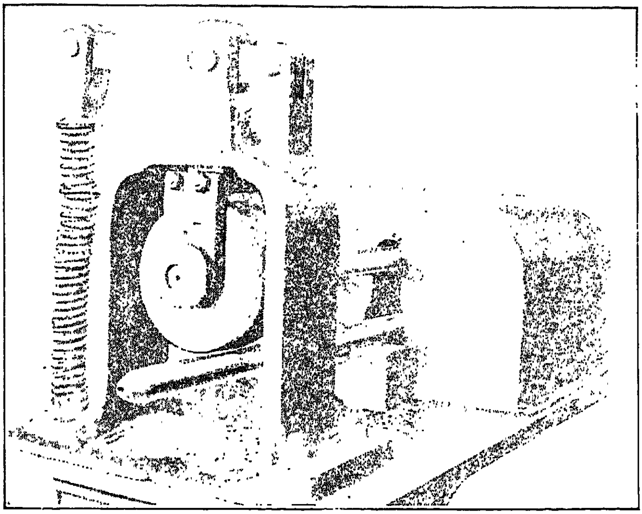


FIG. 277.—Simplest Form of Rolling Machine.

is still giving fairly satisfactory service in two well-known shops today.

Another type, which is more elaborate but more positive, is a three-roller machine, shown in Fig. 278. The mandrel here is stationary and the three idling rollers, being mounted on a power-driven head, continually revolve around it. After inserting the tube, which is also held stationary, pressure is applied by means of a hand lever which closes the three rollers in toward the center of the mandrel and the joint is rolled down by the surface pressure of the three rollers revolving around it. In order to still further insure uniform rolling, the tube is turned slightly on the mandrel three or four times

during the rolling operation since the mandrel is slightl smaller than the tube and if the latter were to be held in onl one position, a difference in wall thickness on one side migh result.

Rolling machines of the types just described are sometime located in direct alignment with the jaws of the weldin machine, so that after obtaining the proper heat, it is onl necessary to release the jaws and shove the hot tube directl

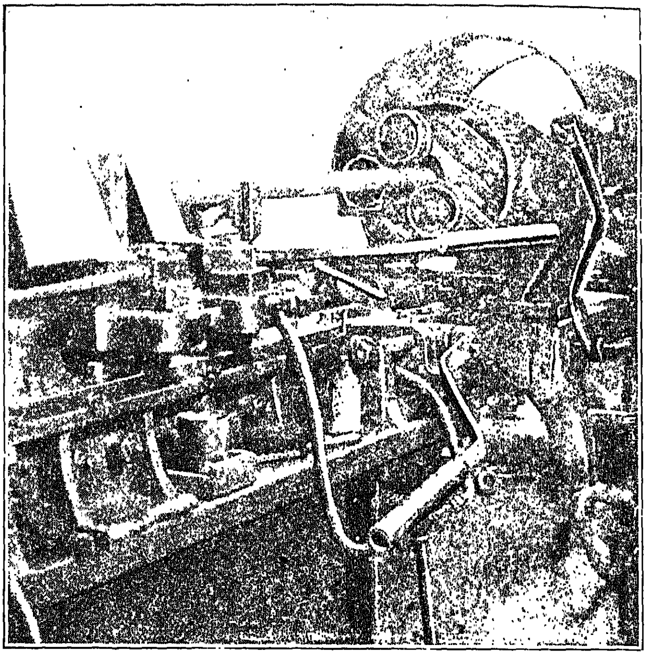


FIG. 278.—The Three-Roller, or Hartz Type, Machine.

onto the mandrel. If the three-roller type is being used, the tube is held stationary by locking one jaw of the welding machine. When a new position on the mandrel is desired the jaws are released and the tube allowed to turn slightly with the friction of the revolving rollers.

Another method is to have the rolling machine in back of the welding machine so that when the correct heat is obtained. the tube is lifted out of the jaws by the operator's assistant

who shoves it onto the rolling mandrel, leaving the operator free to get the next tube lined up in the machine for heating. In this last method, the assistant must act quickly so as not to allow the joint to cool down before the rolling, as he cannot transfer the tube from the welding to the rolling machine as quickly as the operator could shove it forward onto the mandrel as first mentioned.

As to speed in welding, the writer observed that the same production could be obtained in different shops by either method of locating the rolling machine; hence it is purely a matter of space available around the welding machine, and local opinion.

A third way of handling the rolling down is to have the rolling machine built onto the welding machine, as shown in Fig. 279. In this particular apparatus, the mandrel is made long enough to permit welding in to a distance of 10 ft. from the joint, so as to reclaim old short tubes by making a new long one with a joint in the middle. This reclaiming of tubes has proved to be perfectly practical, having been forced in one locomotive shop during the war due to the inability to obtain new tube stock. The mandrel is power driven as well as the upper roller, while the two lower rollers are idlers. After obtaining the welding heat, it is only necessary to move the tube about one foot to bring the joint onto the rollers. A clutch at the rear end is then thrown in to revolve the mandrel and upper roller, and pressure is applied through the latter by means of an air cylinder mounted above it. While being rolled the tube is allowed to revolve freely in the open jaws of the welding machine. The rear end of the tube is supported on idling rollers.

After the rolling-down process, which is the same as has always been used with the oil-furnace method of welding, the tubes are subjected to the annealing and end-swaging processes. They are then usually tested hydrostatically for possible leaks and stacked away ready for assembling in the boiler. The percentage of leaks is less than 5 per cent in any shop, and in one shop they are so sure of their welding that the tubes are not tested until completely assembled in the boiler when the latter is subjected to a hydrostatic test as a complete unit. This particular shop uses the flash-weld method and has never

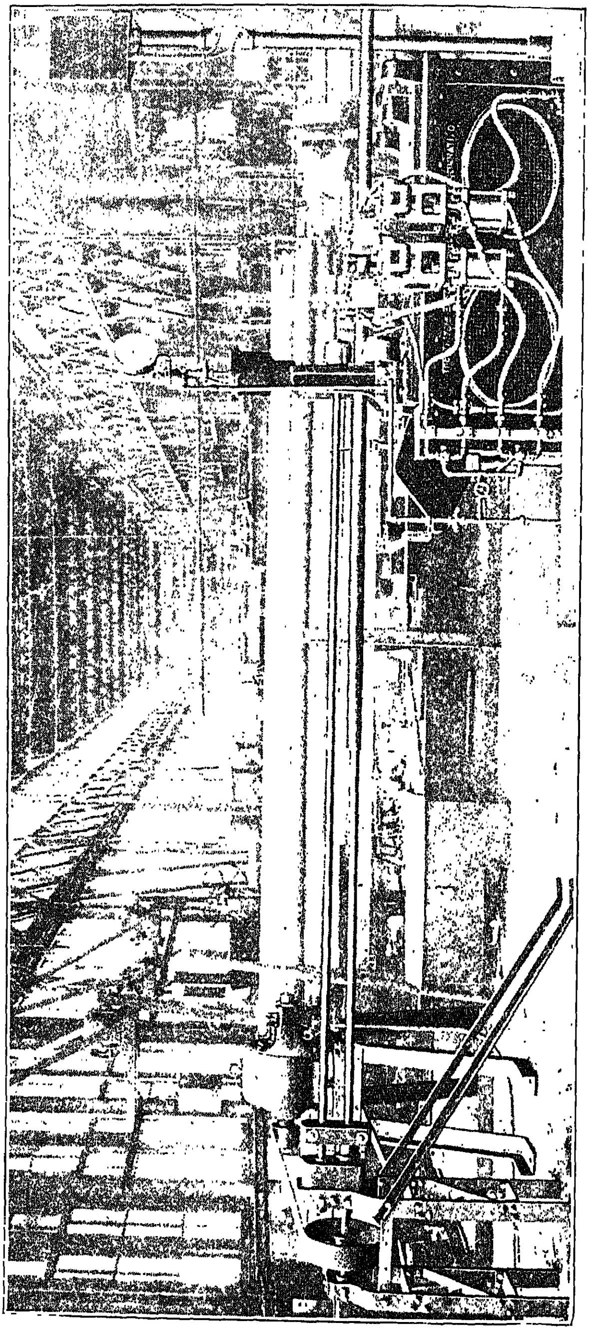


FIG. 279.—Electric Welding Machine with Built-On Rolling Device.

had a defective joint since the welding machine was installed over four years ago.

Merits of Electric and Oil Heating.—When asked to compare the electric welding with the oil-furnace method on boiler tubes of any size, one of the oldest users of the former replied that there was "no comparison." Using oil it was never possible to average over 30 or 40 welds per hour on tubes up to 3 in. with one furnace and one gang. This meant that the tube shop was always behind the rest of the repair departments and working overtime a great deal in order to catch up. Fuel oil will vary greatly in different lots as well as under different atmospheric conditions, so the oil furnace itself is a constant source of aggravation and calls for continual adjusting, which means an interruption in production while the fire is regulated.

As to production with an electric-welding machine, the average output on tubes up to 3 in. in diameter, taken from all shops using this process, will run 60 completed welds per hour, requiring one operator and a helper at the machine and a third man to prepare the work for welding. In the days of piecework, in some of the shops, records show that the maximum number of small tubes turned out in any shop, with the same number of men, was 125 per hour or a little better than one tube every 30 sec. and this could be kept up for two hours at a time without greatly tiring the men. This speed was obtained by three different shops, each using a different style and arrangement of rolling-down apparatus, which shows that all of the methods outlined previously in this article are equally fast.

On welding superheater tubes at the reduced section, where the diameter at the point of weld is about $4\frac{3}{8}$ in., the production will run about 10 to 20 welds per hour, although better time has been made on piecework. By comparing these figures with the oil-furnace welding production, even under the best of working conditions, nothing further need be said as to the speed of the electric process.

As to cost, there are no figures available later than 1916, which of course would be much lower than at the present day, but by comparing costs of both methods at that time, taking into consideration upkeep, labor, cost of heat either way and

cost of time lost by making adjustments or repairs to eithe apparatus, the electric costs per 1,000 tubes welded, is abou one-third that of the oil-furnace method.

The only wear on the welding machine is the surface o the copper dies or jaws which grip the pieces and this is s slight as to only require smoothing off a few times a week The machine does not cost anything for heating energy excep when the weld is being made and it is always ready for actio as soon as the operator has placed the work in the jaws. Henc there is no delay in starting up the fire in the morning o after lunch hour nor from the fire balking at any time durin the welding. The replacements on welding machines in al the shops visited by the writer could be easily covered by $10(during the last six years.

In recapitulating the three methods of electric welding flues it is safe to say that the flash-weld, which produces a scarfed joint when finished, takes the lead for simplicity of preparation, speed of actual welding and reliability as to percentage of failures in any lot of tubes.

Next to this comes the straight scarf-weld, which requires machining of the ends before welding but insures a good joint after welding although occasionally a small leak will show up on the first hydrostatic test. As stated before, the percentage of leaks is very low with this type of weld and practically negligible with the flash-weld.

The butt-weld, which was originally employed in all the shops, is now only used in one shop in the whole country, probably due to the difficulty in making a perfect weld each time as compared to the ease of making a scarf weld. However, this one shop claims very high efficiency with a butt-weld, both as to tensile strength, which will average over 85 per cent of original tube section, and as to tightness of the joint under pressure.

The principal objection offered by most shops against butt-welding is that should the weld prove tight under pressure, but still be a weak joint mechanically, it might break apart in service. This has happened in a few cases, allowing the tube to drop down in the boiler and subjecting the engine crew to the danger of scalding. With a scarf-weld, which generally shows a tensile strength equal to that of the original

tube, due to the area of the weld, should the tube not be welded strongly as just cited and a break should occur inside the boiler, the scarf would prevent the tube from pulling away from its end and only a slow leak could result. This sometimes actually happens with oil-furnace welded tubes.

The Kind of Machine to Use.—As there are different styles and sizes of welding machines being used at the present time on flue-welding, the writer will endeavor to specify special characteristics that should be sought when selecting a machine for this class of work, which is different from any other pipe-welding job. The machine should be constructed to be as efficient electrically as possible; that is, the clamping jaw should be as close to the transformer as is practical in order not to

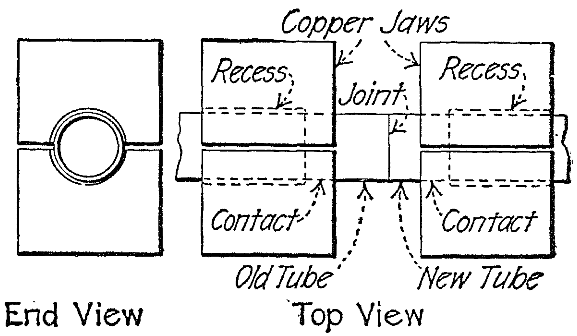


FIG. 280.—Recessed Copper Clamping Jaws.

have large inductive losses caused by the large gap due to the long secondary leads widely spaced. The fewer the joints between the secondary loop of the transformer and the copper jaws which grip the tube, the less chance will there be for resistance losses that cut down the heating effect gradually as oxides form in the joints or by dirt collecting from allowing them to become loose. Although the jaws should be long to permit thorough water cooling, it is only necessary to grip the pipe over a length of about 2 in. This length is bored out to exactly fit around the tube as shown in Fig. 280.

The pressure device does not need to be as heavy as would be used on the same welding machine for joining ordinary pipe or solid stock, since the squeezing together of the plastic metal

is really done in the rolling machine. For fastest operation th clamping jaws should be operated by air cylinders so that onl a slight movement of two valves is necessary to lock or unlocl the tube in the jaws.

For welding up to 3-in. size tubes, a machine of 30-kw rating ought to be large enough to stand constant use. An form of toggle lever or screw-wheel pressure device, whicl permits the operator to stand close to the work will be suitable as not over 1,000 lb. effective pressure is required on this siz of work to stick the ends together sufficiently hard for placin in the rolling machine.

To handle up to $5\frac{3}{8}$-in. superheater tubes, a machine o about 75-kw. rating should be employed. For its pressur device, an air cylinder or hydraulic apparatus may be use to best advantage so as to secure up to three or four tons maximum effective pressure.

For ordinary butt- or scarf-welding, a hand-operated oil jack may be used, although trouble has been experienced in the past with this type of pressure device due to sticking of the valves at critical times, often spoiling a weld.

Flash-Welding.—For flash-welding, a toggle lever or hand-screw wheel on small machines and an air cylinder or hydraulic pressure device on large machines must be used, to effect a slow steady forward movement of the movable jaw in order to maintain the arc of the flashing, yet to have available a quick reverse to break the parts away should they stick too soon from too rapid movement of the pressure device. In small shops, it is advisable to install a 75-kw. machine to handle all sizes of tubes up to the largest superheater. If the shop is large enough to keep a small machine busy all the time on tubes up to 3 in., it will no doubt pay to install in addition, a large machine just to handle the superheater tubes as well as any overflow lot of small tubes. While the large machine will handle any size, it is not so rapid in operation on small tubes as the smaller one, and the bulk of flue-welding is on small tubes, less than 10 per cent of the total being represented by the larger sizes for superheaters.

WELDING IN THE TOPEKA SHOPS OF THE SANTA FE RAILROAD

Supplementing the foregoing, we give the following extract from an article published in the *American Machinist*, June 8, 1916:

In order to give the gripping jaws of the welder good, clean contact the ends of the pieces are ground on the outside for about 6 or 7 in. back from the ends, the operator simply

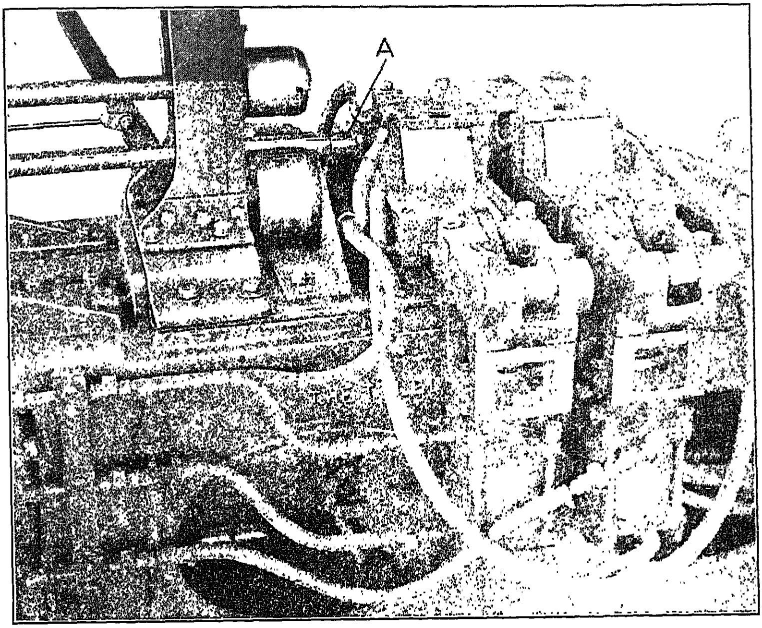


FIG. 281.—Close-Up Showing Inside Mandrel.

revolving the tube end against the grinding wheel. The ground pieces are sorted out into suitable lengths to form full-length flues when two pieces are butted together, keeping in mind that only two welds are allowed to a flue.

The butt-welding machine itself is practically as received, but the inside mandrel and outside rolls, together with the driving mechanism, were added in the shop after considerable experimenting. Without these the method would be a failure.

A close-up view of the machine, from the back, is given in Fig. 281. This shows the mandrel *A* that works inside the

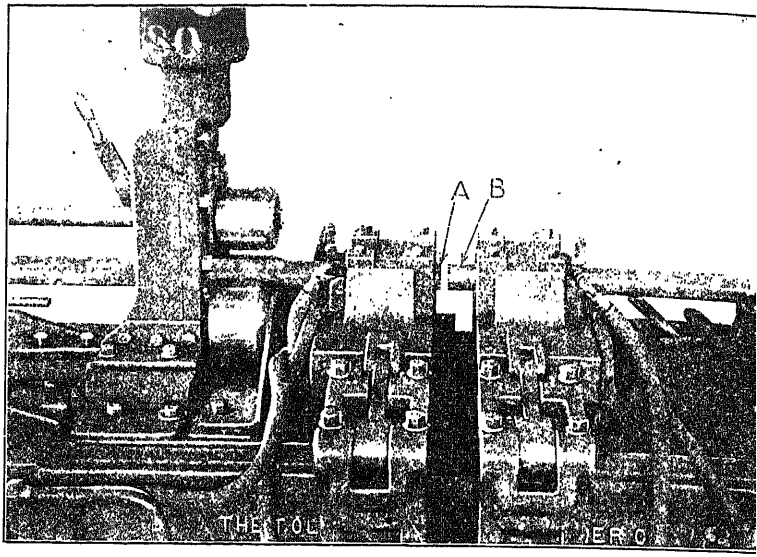


FIG. 282.—Flue Parts Ready for Welding.

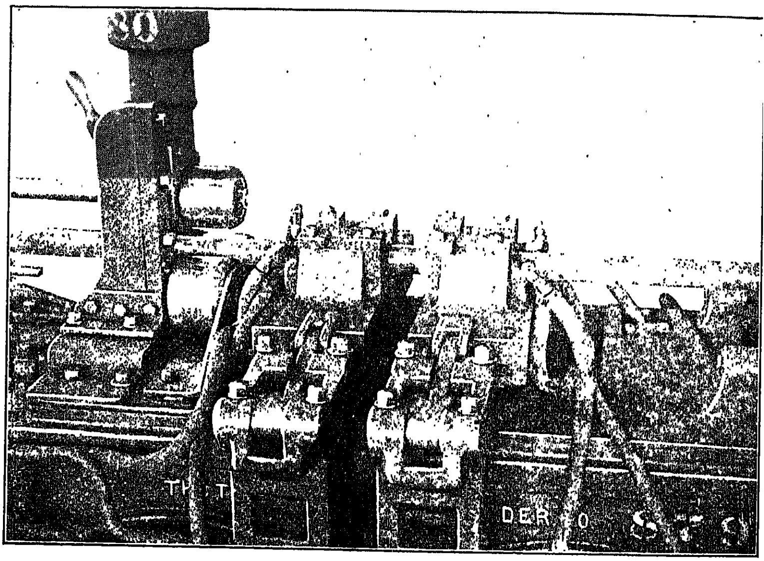


FIG. 283.—Flue Ends Just Beginning to Heat.

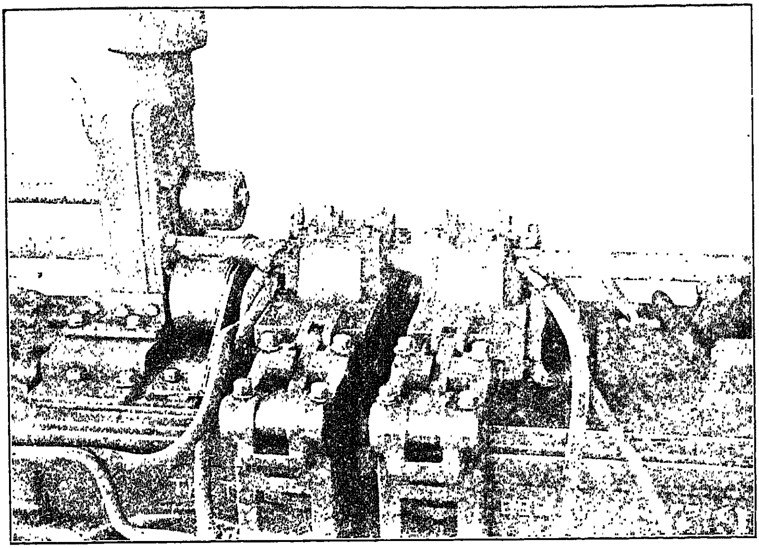


FIG. 284.—Almost Hot Enough for Welding.

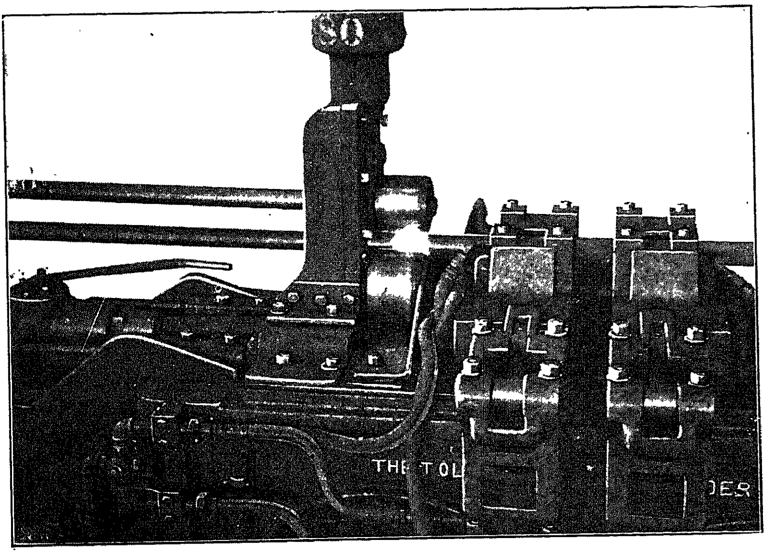


FIG. 285.—Rolling Out the Upset Metal.

flue as the outside is rolled between the three rolls after th parts have been heated and butted together. The action of the mandrel and rolls is to take out the upset and give a wel that is smooth on the outside and with very little extra meta inside. The gripping jaws are water-cooled, and the operatin air cylinders are plainly shown.

Fig. 282 shows two parts of a flue in place in the jaw and illustrates how it is slipped over the mandrel. It wil be observed that the mandrel does not extend far enougl beyond the rolls to interfere with the welding or become heatec from the current passing between the jaws. As it is impossibl always to have the two parts to be welded of the same thickness, the setting of the pieces in the jaws must be done witl judgment. If one piece is thinner than the other and they were both set in the jaws the same distance out, the thin one would burn before the thick one was hot enough to weld properly. To avoid this, a thick and a thin piece are placed about as shown at *A* and *B*. In this case the thick one is at *A* and the thin one at *B*. As the thick one is in closer to the jaw, it will heat faster. The thin one, being set out farther, gives practically the same amount of metal for the current to heat. The result is an even heating and a perfect weld.

Fig. 283 shows two pieces the reverse of the ones just shown. As the work gradually heats, it looks as in Fig. 284. At the proper heat, the operator butts the work together to form the weld, which leaves a considerable amount of upset. He then shoves the tube along over the mandrel until the weld is between the rolls, when he throws in the clutch and brings down the upper roll. The work spins between the rolls, as shown in Fig. 285 and the result looks almost like a new tube.

CHAPTER XV

ELECTRIC WELDING OF HIGH-SPEED STEEL AND STELLITE IN TOOL MANUFACTURE

The cost of solid high-speed cutting tools is high. At the same time their remarkable cutting qualities make them a necessity in up-to-date shop practice. The electric process of butt-welding has made it possible to obtain all the advantages of a solid high-speed cutting tool and yet at a cost that is not a great deal higher than the ordinary tool-steel product. Stellite, which has recently become more widely known, has been rather limited in its use owing to the fact that it cannot be machined, and it has been thought by many that it could not be successfully joined to any other metal for holding it. This has limited its use to special forms of toolholders, which are often very clumsy in getting into difficult corners on special shapes. The electric process of butt-welding has made it possible to join Stellite bits of any common size and shape to a shank of ordinary steel, giving all the advantages of a solid cutting tool and yet employing only a small amount of the Stellite metal just where it is needed for cutting.

The Thomson welding process consists of passing a large volume of electric current at a low pressure through the joint made by butting two pieces of metal together. The electrical resistance of the metals at the contacting surface is so great that they soon become heated to a welding temperature. Pressure is then applied mechanically and the current turned off, thereby producing a weld. The metal is in full view of the operator at all times instead of being hidden by the coal of a forge or by flame in an oil furnace. No smoked glasses or goggles are required any more than would be if welding by the forge method. Due to the way the metal is forced together there is no oxidation such as there would be in an open fire and therefore no welding compound is ordinarily required.

It is this feature alone which makes it possible to weld higl speed steel and Stellite, the former being very difficult to wel by the forge method and the latter practically impossibl With this process of electric welding the heat is first develope in the interior of the metal. Consequently, it is welded ther as perfectly as at the surface. When welding with othe methods, however, the outer surface is heated first and ver often the interior part does not reach welding heat, the resul being an imperfect weld. There is no blistering or burnin of the stock when welding electrically, whereas it certainl requires a very expert welder indeed to secure the proper hea on high-speed steel in a forge fire without burning at som point. The process is the most economical known, due to th fact that no energy in the form of heat is being wasted i heating more of the material than is required to make a wel and as soon as it has been completed the current is turne off so that the machine then is not using up any energy what ever. The operator has complete control of the current at al times so that he can obtain any color desired on the metals where are always visible, and waste by accidental burning o metal is reduced to a minimum.

The only preparation of stock necessary for welding by this process is that when very rusty or greasy it should be thoroughly cleaned, as the presence of either rust or heavy grease affords poor contact with the copper clamping jaws, retarding the flow of electricity and seriously reducing the heating effect.

It is often asked if the electric current has any effect on the welded metal. This question arises from the fear that there may be some mysterious condition connected with electricity that will change the characteristics of the metal, particularly of high-speed steel or Stellite. The answer is, of course, in the negative, as the only effect of the electric current is to heat the metals being welded.

The rapidity of work will depend largely on the operator, the size and shape of the pieces to be welded and the size of machine being used, as there is a wide range in welding time between heavy pieces requiring careful alignment in the clamping jaws and light pieces which can be rapidly and easily handled.

Welding High-Speed to Low-Carbon Steel.—In tool welding

there are various kinds of welds to be made, which require different designs of holding jaws and often two distinct types of welding machine.

Three butt-welding machines shown in Figs. 286, 287, and 288 are especially suitable for welding drills, reamers or other

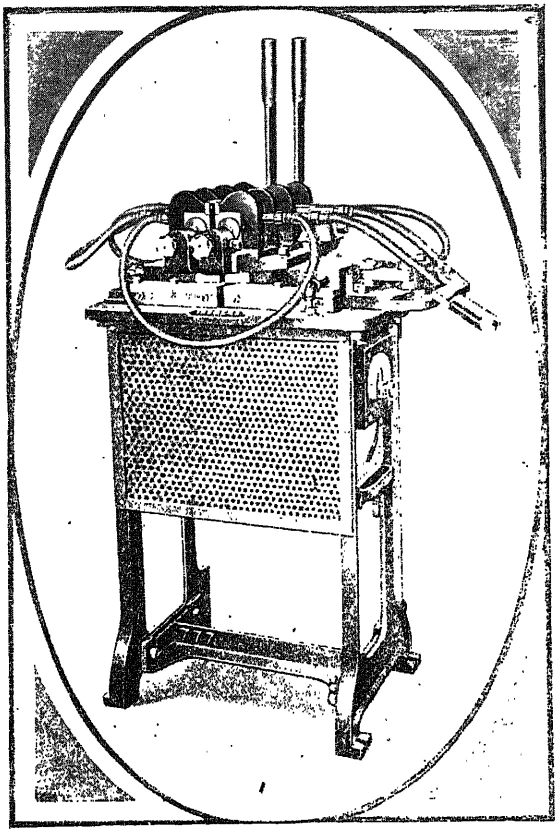


FIG. 286.—Thomson 10-A6 Butt-Welding Machine.

tools that can be made up of a combination of high-speed and low-carbon steel. The machine shown in Fig. 286, known as the 10-A6 machine, will weld iron or steel rods from $\frac{1}{4}$ to $\frac{3}{4}$ in. in diameter, or an equivalent cross-section in squares, rectangles or flats. An operator can make from 50 to 200 welds per hour, according to the size and nature of the work being handled.

The clamps are of the horizontal operating type, adjustable for different sizes of stock as well as for horizontal alignment of the work. A close-up view of the left-hand clamping mechanism is shown in Fig. 287. The jaw blocks are water cooled and have a maximum movement of $1\frac{1}{2}$ in. by means of the hand-operated clamping levers. There is also a possible $\frac{3}{4}$-in. adjustment of both front and rear jaw blocks. Stops are provided for backing up the work. There are four copper jaws to a set, two being used on each clamp. These jaws are

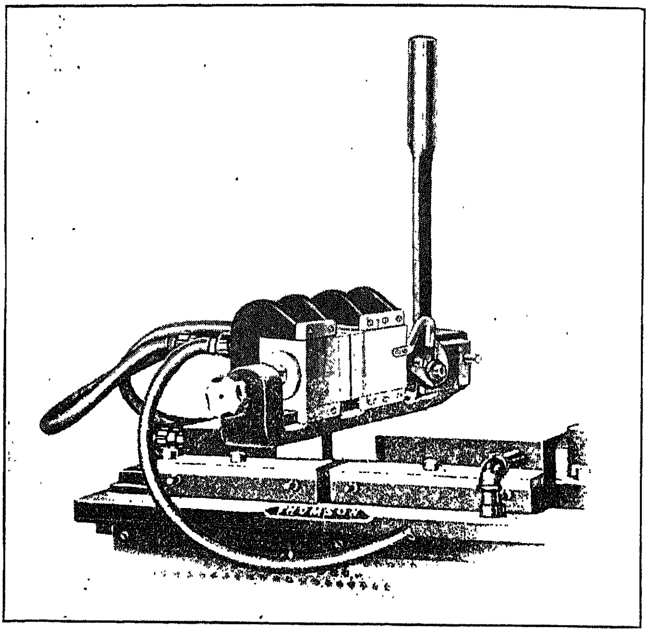


FIG. 287.—Closeup View of Left-Hand Clamp.

$2^1/_2$ in. square by $1^7/_{16}$ in. thick. The pressure device for forcing the heated ends of the work together is a hand-lever-operated toggle movement, which enables the operator to "feel" his work. This toggle device gives a movement of 1 in. to the right-hand jaw. The maximum space possible between the jaws is $3\frac{1}{4}$ in. There is an automatic current cutoff mounted on the machine. The standard windings are for 220, 440 and 550 volt, 60-cycle alternating current. The current variation for different sized stock is effected through a five-point switch

mounted on the machine. Standard ratings are 15 kw., or 25. k.v.a., with 60 per cent. power factor. This size of machine covers a floor space 43×57 in., is 65 in. high and weighs about 1100 pounds.

The machine shown in Fig. 288, or the No. 6 machine, is for heavier work, its capacity being from $\frac{1}{4}$ to 1 in. in diameter on iron or steel rods, or the equivalent in other shapes. Its production is from 50 to 125 welds per hour. The maximum jaw opening is 3 in.; the four jaws are of hard-drawn copper, $2\frac{1}{8}\times2\frac{5}{8}$ in. and $1\frac{1}{4}$ in. thick; toggle-lever movement $1\frac{1}{2}$ in.;

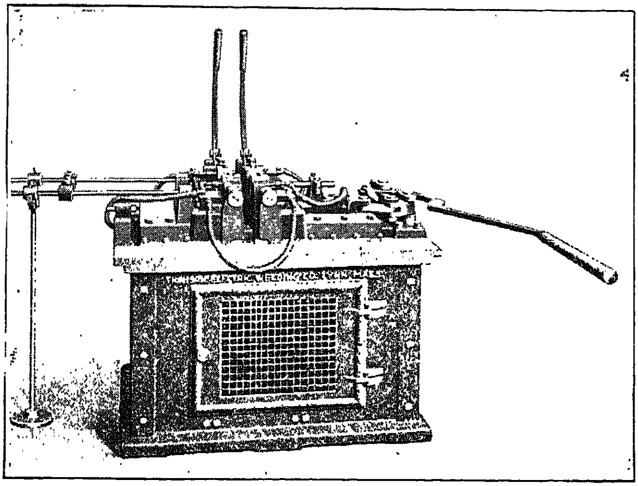


FIG. 288.—No. 6 Butt-Welding Machine.

maximum space between jaws, 4 in.; current standards are the same as for the previous machine. There are 10 points of current variation for different sized stock, effected through double-control switches mounted on the machine. Standard ratings are 30 kw. or 45 kva., with 60 per cent. power factor. The jaws are air cooled, but the copper slides to which the jaws are bolted, as well as the secondary copper casting of the transformer, are water cooled. It occupies a floor space 22×44 in. and the height to center line of the jaws is $37\frac{1}{8}$ in. The weight is 3100 lb. Its operation is practically the same as the first machine described.

Another machine of very similar characteristics is shown

in Fig. 289. This is known as the Special 5-D machine and is intended for the use of makers of small taps and twist drills up to $\frac{5}{8}$ in. in diameter. It has very accurate adjustments on

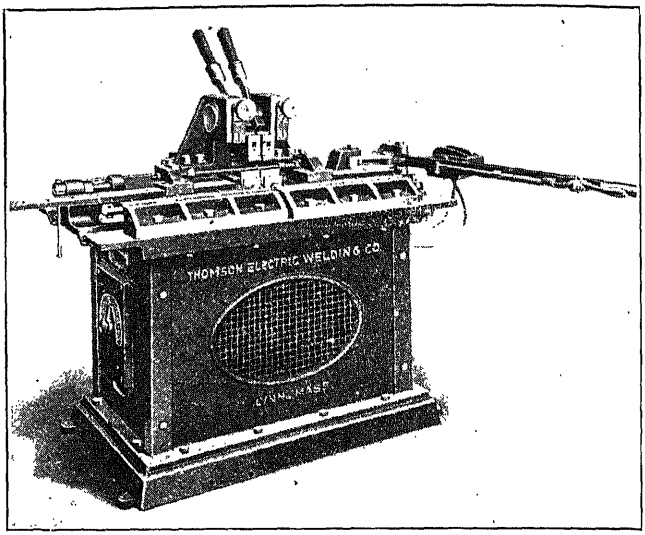


FIG. 289.—Special 5-D Machine.

the clamps and special jaws with steel inserts to prevent wear. To use these, however, requires that the pieces to be welded must be finished to uniform size so as to accurately fit the jaws in order to conduct the current properly.

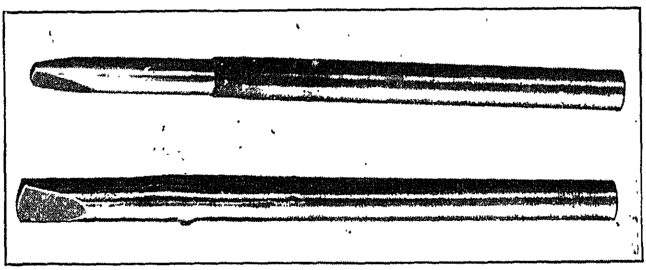


FIG. 290.—Stellite-Tipped Roughing Drills.

The machines shown in Figs. 286 and 288 are not only good for welding the steels mentioned, but also for Stellite work, samples of which are shown in Fig. 290, since the com-

monly used bits of this metal are within their range. The hand-lever toggle action is quicker and is better suited to this work than the hydraulic-pressure device used on some of the larger machines.

In welding twist drill or reamer blanks, such as shown in Fig. 291, not over $\frac{3}{4}$ in. in diameter, it has been found practical

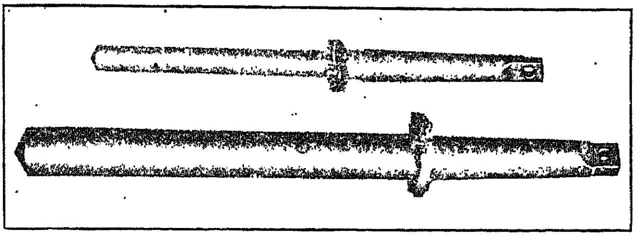


FIG. 291.—Twist-Drill Blanks Just Welded.

to use a pair of jaws on each side that will handle all work from the smallest up to the $\frac{3}{4}$-in. size. These jaws are made as shown in Fig. 292. The two rear, or movable, jaws on each side of the machine are flat faced, while the front, or stationary, jaws, have a V-groove cut in them just deep enough to give clearance for the smallest size of stock to be handled in contact

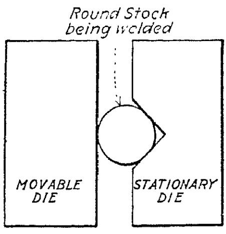


FIG. 292.—Copper Jaws for Various Sizes.

with the face of the opposite jaw. The work is held in the jaws with a three-point contact, which has been found to be sufficient for stock of this size, although it is not to be recommended for larger work, since not enough current could be carried into the pieces without applying pressure sufficient to squeeze the work into the surface of the copper jaws. This would soon spoil all accuracy of alignment of the V-grooves.

In this connection it may be well to mention that a weldir machine is not a micrometer and the welding of finished piec is not recommended in commercial production, although su welding is done right along for special jobs. By "speci jobs" is meant the putting on of an extension to a drill, ta or small reamer and the like.

In welding high-speed to low-carbon steel the low-carbo steel should project approximately twice as far out from tl jaws as the high-speed steel does in order to equalize as muc as possible the heating of the two pieces.

Where a tool is to be made with a head larger than tl shank, as shown at *A*, Fig. 293, holding copper jaws shoul

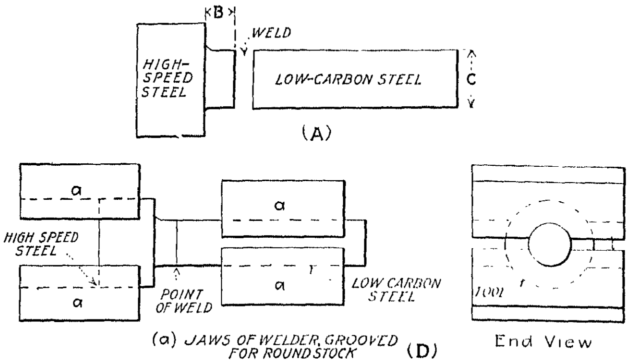


FIG. 293.—Copper Jaws for Holding Large Heads and Small Shanks.

be made as shown at *D*. In work of this kind the dimensior *B* should always be about one-half of the diameter of *C*. Th same rule holds good with this type of tool blank when placing it in the jaws as with steel of the same relative size; that is, the low-carbon steel should project about twice as far from the jaws as the high-speed steel since the high-speed steel has the higher resistance and has a tendency to become plastic sooner. To still further reduce its tendency to heat up quickly, the resistance should be reduced as much as possible by having the jaws as good a fit for the high-speed piece as it is possible to make them. Where different sizes are to be welded it is advisable to have special holding jaws for each separate size of high-speed steel head, although the low-carbon steel pieces may be held in V-grooved jaws made up to hold several sizes.

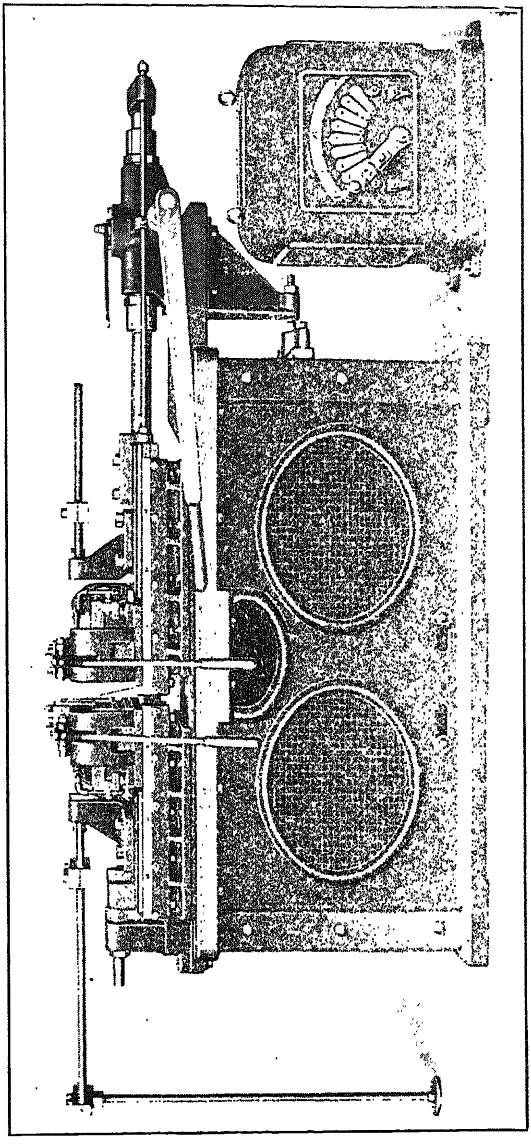


FIG. 294.—No. 9 Butt-Welding Machine.

This is the practice of some of the largest makers of reame and large drills.

The actual use of the machines shown for the work outlin is simplicity itself. The work is placed in the respective ja and securely locked in place by pulling forward the two leve shown projecting upward on each machine. In addition the grip of the jaws the work is kept from any possible sl by means of stops against which the outer ends of the wo are butted. With the work solidly in place the operator pu

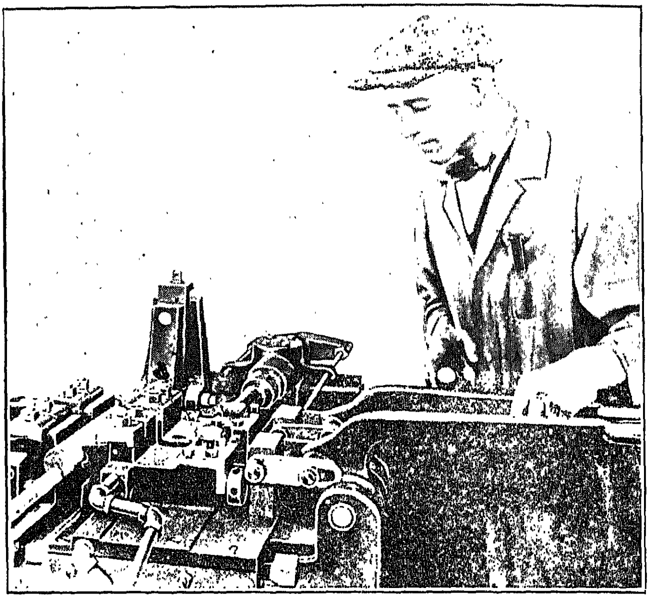


FIG. 295.—Close-up of Machine with Work in Jaws.

on the pressure lever at the right of the machine until th ends of the work are in firm contact. He then turns on th current by means of a push button conveniently located in th pressure lever, and when the proper heat is reached, whic is judged by the color, the push button is released. This shut off the current and the operator then applies full pressure an the weld is made.

The maximum capacity of the largest of the three machine described is 1 in. round or its equivalent in other shapes. Fo larger work a machine similar to the one shown in Fig. 29

is used. This is known as a No. 9 butt-welding machine, and its capacity is from $\frac{1}{2}$ to $1\frac{1}{4}$ in.; the output is from 50 to 100 welds per hour; the maximum jaw opening is $1\frac{5}{8}$ in.; the four hard-drawn copper jaws are 3 in. high, $3\frac{1}{4}$ in. wide and $1\frac{1}{2}$ in. thick; the pressure device is a 5-ton hand-operated hydraulic oil jack; maximum movement with jack, 2 in.; maximum movement with one stroke of jack, $\frac{1}{4}$ in.; maximum opening between jaws, 4 in.; standard windings the same as for the previous machines; standard ratings, 40 kw. or 55 kva., with 60 per

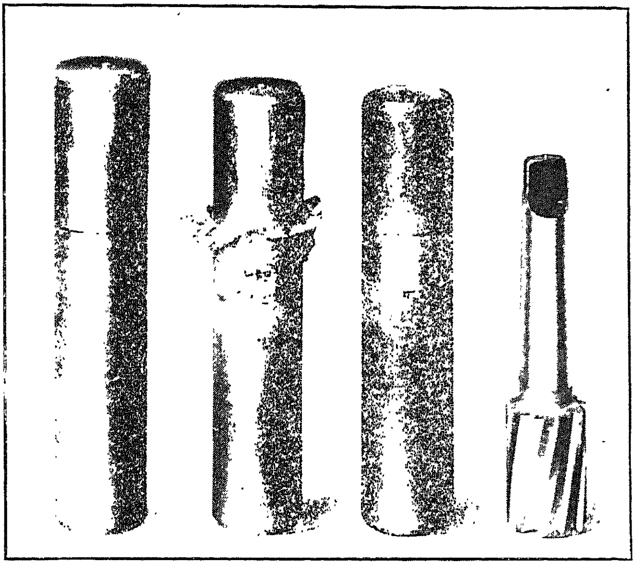


FIG. 296.—Steps in the Making of a Large Reamer.

cent. power factor; width of machine, 27 in.; length, 60 in.; height, 46 in.; weight, 3900 pounds.

A closeup of this machine, with a large reamer blank in the jaws, is shown in Fig. 295, and progressive steps in the making of the reamer are shown in Fig. 296. The high-speed steel piece is 3 in. long by $1\frac{5}{8}$ in. diameter, and the machine-steel piece is 6 in. long.

Two other machines (10-B and 40-A2 models) of this type suitable for heavy tool welding may be mentioned. They are made with a capacity of from $\frac{1}{2}$ to $1\frac{1}{2}$ and from 1 to 2 in.

The first of these has a hand-operated pressure device capabl of exerting a pressure of 12 tons and it weighs 7800 lb. Th second has a pressure device which receives its initial pressur

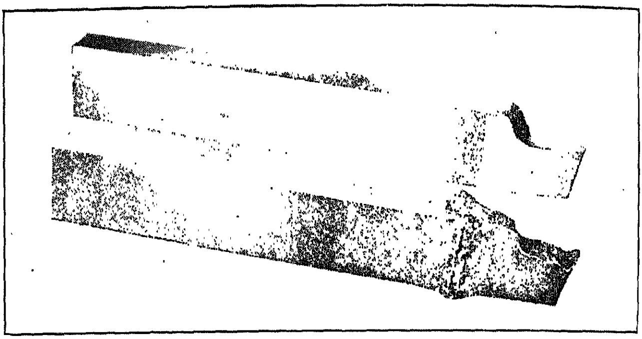


FIG. 297.—A Welded and a Finished Lathe Tool.

from an external accumulator, which gives an effective pres sure of 23 tons; it weighs 8000 lb. and is 64×105×48 in. high

The Welding of Other Than Round Tools.—The welding

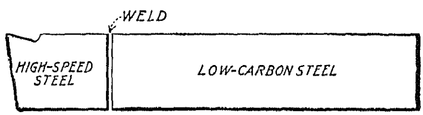


FIG. 298.—How the Parts Are Arranged for Welding.

of tools similar to the ones shown in Fig. 297, intended for lathe or planing-machine tools, may be done in any of the foregoing machines. The cutting parts may be of either Stellite

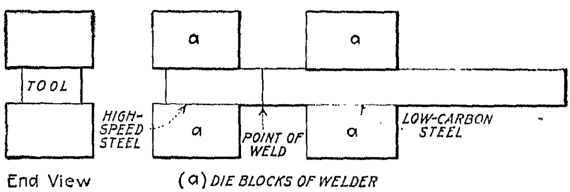


FIG. 299.—How the Parts Are Clamped in the Jaws.

or high-speed steel. This kind of welding is usually employed by manufacturing concerns in their own toolrooms in order to use up odd bits of high-priced steel or Stellite. The pieces are

prepared about as shown in Fig. 298. Jaws for holding work of this kind are outlined in Fig. 299.

Another way to make tools for lathe or planing-machine work is outlined in Fig. 300. This method may often be employed when the one just given could not. As can be seen,

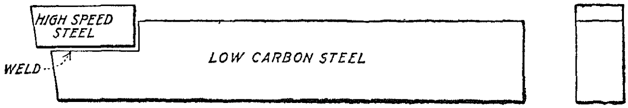


FIG. 300.—Method of Preparing for an Insert Weld.

in order to properly support the high-speed steel piece, the low-carbon steel shank is milled away to form a recess for the reception of the high-speed steel bit. The welding can be done on any of the machines shown provided the parts are not of too great cross-section. The method of recessing the copper clamping jaws is clearly shown in Fig. 301.

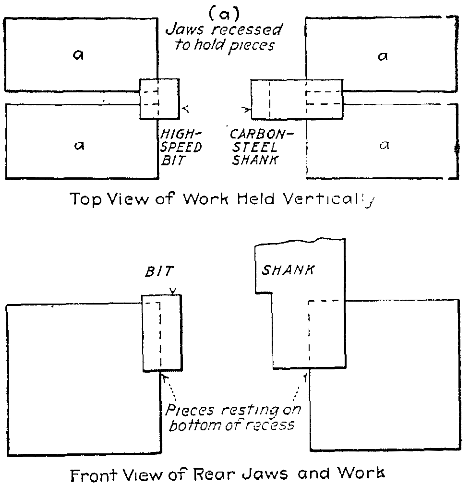


FIG. 301.—Jaws Used for Holding Work in Insert Welding.

The perfect success of a welded high-speed tool depends not only on the correct welding but also upon the correct treatment after the welding itself has been accomplished. It is easily seen that if a piece of high-speed steel is welded to a piece of ordinary carbon steel and the joint allowed to cool

fairly quickly in the air strains will be set up at the joint for the reason that the high-speed steel in cooling so quickly, both metals become hardened more or less but to a different degree. Hence if the weld is subjected to any great strain under these conditions it will break either at the joint or close by, due to the strain. *It is therefore very evident that immediately after welding a piece of high-speed steel to carbon steel the work should be immediately put into some sort of furnace to be annealed.* The amount of time that the tools should be left in the furnace for thoroughly heating through and the amount of time required to allow the pieces to cool down to room temperature depend entirely upon the size and

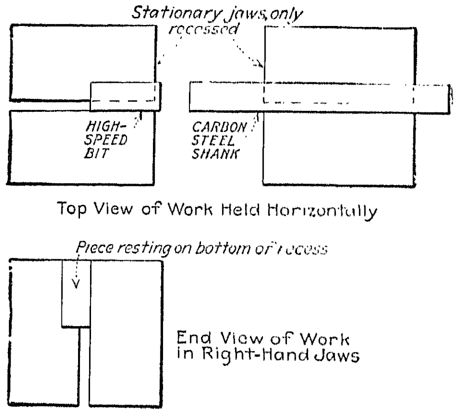


FIG. 302.—Jaws Used for Stellite Butt Welding.

character of tool being made. However, the annealing of any piece of any size requires that the work be left in the furnace heated to at least a dull cherry red for a few hours and allowed to cool very slowly in the furnace.

If a welded tool is not properly annealed before machining much difficulty is often experienced from hard spots being encountered in the machining of the pieces, which of course is more or less disastrous to the cutting edges of the tools being used in the machining process.

The best method of hardening high-speed steel tools after the welding and machining depends also greatly upon the shape and size.

Welding Stellite.—Although the welding of the various

grades of Stellite is not difficult there is a certain knack in the welding and also in the clamping of the stock which must be fully acquired to produce satisfactory results.

The welding should be done in a horizontal butt-welding machine with a quick-acting hand-lever pressure device. In butt-welding round drill stock or rectangular tool stock the pieces should be held as shown in Fig. 302. It will be noticed that the projection of the Stellite beyond the copper jaws is very short indeed while the projection of the carbon-steel

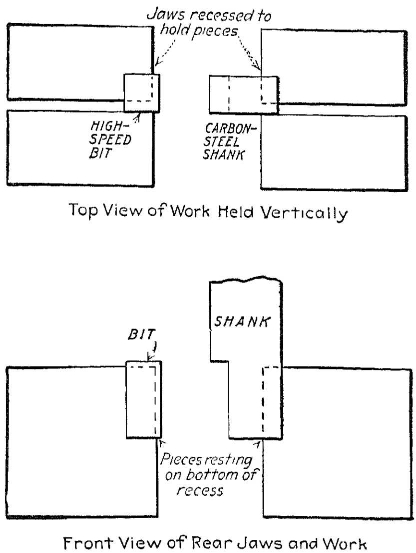


FIG. 303.—Jaws Used for Stellite Insert Welding.

piece is comparatively long. This is because Stellite has a very high resistance compared with the carbon steel. Since in this work the heating effect varies directly with the resistance of two metals the heating in the Stellite should be retarded as much as possible by surrounding it almost completely with the copper jaws. The correct amount of projection of the carbon steel will have to be determined by experiment in each case after observing with each setting of two pieces which has the tendency to heat the fastest.

In welding in cutting bits of Stellite by the insert-weld method the pieces should be held as shown in Fig. 303.

It will be seen from this cut that the copper jaws holding the small bit nearly surround it and at the same time back up the piece to take the pressure of the squeezing up of the

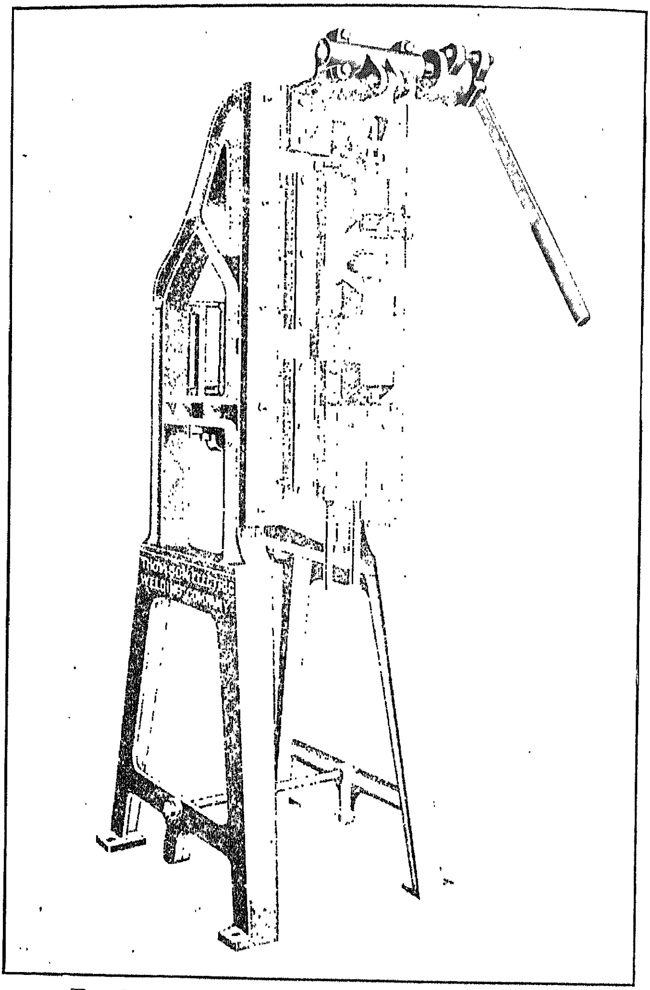


FIG. 304.—Vertical Type of Welding Machine.

stock. The opposite jaws holding the carbon-steel shank do not have to grip very much of the metal but they serve to back it up to receive the force of the pressure.

In the welding itself the current is applied intermittently,

as the Stellite usually has a tendency to heat very rapidly, until the carbon steel is fast approaching the plastic state. The current is then held on steadily and the instant the Stellite metal "runs," the pressure lever is given a quick jerk as the current is turned off. It will be found that with a good weld there is scarcely any push up of the stock and very little of the

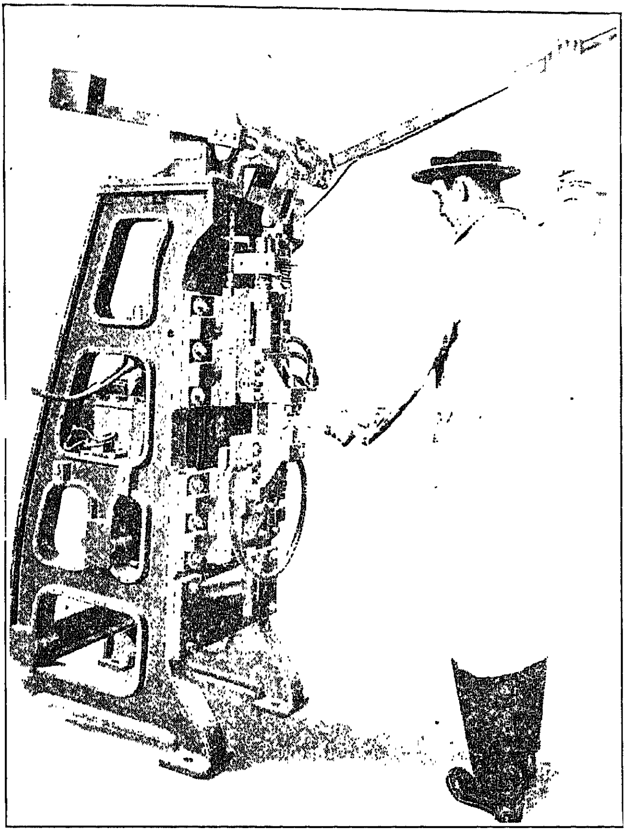


FIG. 305.—Making a "Mash" Insert Weld in a 20-AV Machine.

metal flows out at the joint, requiring little grinding, if any, to finish the tool.

Unlike high-speed steel Stellite requires no further heat treatment or attention of any kind if it is welded correctly. When it is taken out of the welding machine the tool is ready for use at once after grinding off the resulting burr.

Where large numbers of tools of the lathe and planing-machine types are to be made, such as shown in Fig. 300, the highest production can be obtained by using a vertical

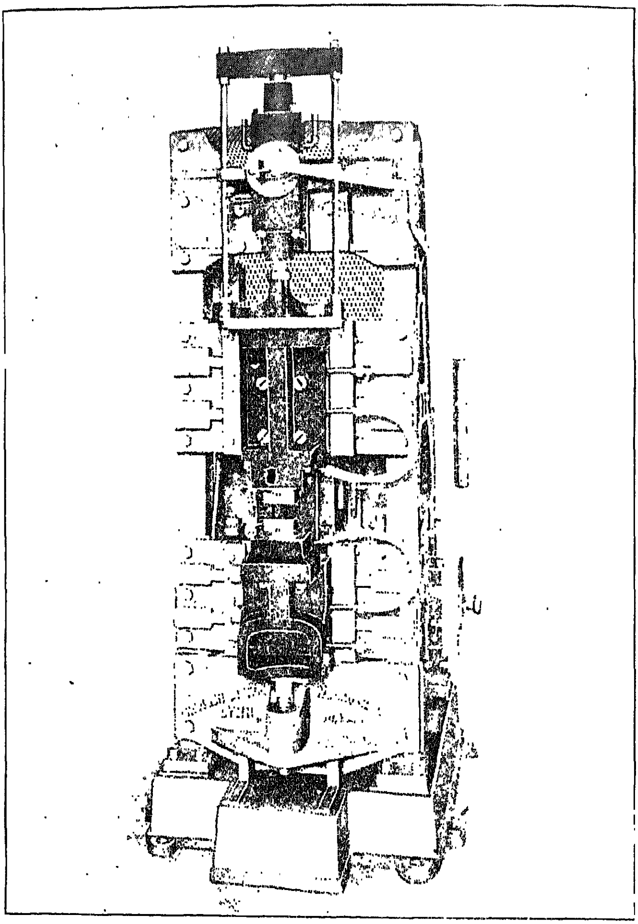


FIG. 306.—Large 40-AV Vertical Machine.

type of welding machine built on the lines of the one shown in Fig. 304.

This machine (10-AV model) has a capacity of two pieces with contact areas between 0.40 and 0.30 sq. in. for pieces with a total thickness of $\frac{3}{4}$ to $1\frac{1}{4}$ in. The production is 35 to 85 tools per hour, depending on the size; the upper and lower

jaws are of hard-drawn copper $1\frac{3}{4}\times 2\frac{1}{4}$ in. and $1\frac{7}{8}$ in. thick; the jaw blocks are water cooled; the machine has a current variation through a five-point switch for different sizes of stock; standard windings are for alternating current 220 440 and 550 volt, 60 cycles; standard ratings, 15 kw. or 25 kva. with power factor of 60 per cent.; the pressure device is hand operated, giving a movement of $2\frac{3}{4}$ in.; maximum space between jaws, $3\frac{1}{4}$ in.; floor space occupied, 21×53 in.; height, 75 in.; weight, 1200 pounds.

A larger machine (20-AV model) of the same type in operation is shown in Fig. 305. This machine gives a maximum area of contact ranging from $1\frac{1}{4}$ to 1 sq. in. on pieces with a total thickness from 1 up to 2 in.; production is from 50 to 75 welds per hour; there is a throat clearance of 10 in.; the copper jaws are 2×3 in. and $1\frac{1}{2}$ in. thick; pressure is by hand-toggle

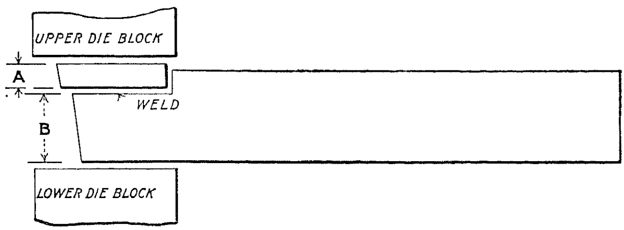


FIG. 307.—Jaws and Work Arranged for a "Mash" Weld.

lever and spring cushion; current control, as in the other machines, is by push button in the lever operating through a magnetic wall switch; the jaw blocks are water cooled; standard ratings are 30 kw. or 50 kva. with 60 per cent. power factor; weight, 2200 pounds.

Another still larger machine (40-AV model) is shown in Fig. 306. Except for its size it is but little different from the two just described, the main difference being the hydraulic-pressure device, which gives an effective pressure of 5 tons. This machine has a maximum contact area of 3 sq. in. and will weld pieces from $1\frac{1}{2}$ to 3 in. total thickness; production, 15 to 50 welds; throat depth, $6\frac{1}{4}$ in.; jaws, $2\times 4\times 1\frac{1}{2}$ in. thick; maximum movement of upper jaw block, 2 in.; movement with one stroke of lever, $\frac{3}{8}$ in.; space possible between jaws, 3 in.; standard ratings, 60 kw. or 86 kva. with 70 per cent.

TABLE XXVI—CURRENT CONSUMPTION FOR WELDING VARIOUS SIZES

Diameter of rod, inches		Dia. of rod, millimeters	Area of section, sq. in.	Current consumption per 1000 welds	Cost per 1000 welds at 1 cent per K.W.H.*	Diameter of rod, inches		Dia. of rod, millimeters	Area of section, sq. in.	Current consumption per 1000 welds	Cost per 1000 welds at 1 cent per K.W.H.*
Decimal	Fraction					Decimal	Fraction				
.25	1/4		.04909	10	$0 10	1.2598		32	1 245	270	$2 70
.2755		7	.0596	11	.11	1.3385		34	1.407	320	3 20
.3125	5/16		.0767	12	.12	1.375	1 3/8		1 4849	340	3 40
.3149		8	.0779	12	.12	1.4173		36	1 576	360	3 60
.3543		9	.0987	14	.14	1.496		38	1 757	425	4 25
.375	3/8		.11045	15	.15	1.5	1 1/2		1.7671	430	4 30
.3937		10	1217	16	.16	1.5748		40	1 946	470	4 70
.4724		12	.1753	19	.19	1.625	1 5/8		2 0739	530	5.30
.5	1/2		.19635	20	.20	1.6535		42	2 146	540	5 40
.5612		14	.2472	26	.26	1.7322		44	2,356	600	6 00
.625	5/8		.3068	30	.30	1.75	1 3/4		2 4053	640	6 40
.6299		16	.3115	34	.34	1.811		46	2 576	700	7.00
.7087		18	.3946	45	.45	1.875	1 7/8		2.7612	780	7 80
.75	3/4		.44179	52	52	1.8897		48	2 802	810	8.10
.7874		20	.487	60	60	1.9685		50	3 089	870	8.70
.8661		22	.585	80	80	2.	2		3 1416	930	9 30
.875	7/8		.60132	85	.85	2.0472		52	3 286	1000	10 00
.94488		24	.701	105	1.05	2.125	2 1/8		3 5466	1100	11 00
1.	1		.7854	130	1.30	2.1259		54	3 55	1130	11 30
1.0236		26	.822	135	1 35	2.2047		56	3 82	1200	12.00
1.1023		28	.944	180	1.80	2.25	2 1/4		3.9761	1280	12.80
1.125	1 1/8		.994	190	1.90	2 2834		58	4 095	1350	13 50
1.1811		30	1 094	230	2.30	2.3622		60	4 387	1460	14 60
1.25	1 1/4		1.2272	265	2 65						

* Multiply these values by the rate you are paying per K.W Hour for current, to determine what the cost per 1000 welds for any size would be at your plant.

TABLE XXVII—SIZES OF COPPER WIRE FOR CONNECTING UP DIFFERENT SIZES OF WELDING MACHINES

Type Machine	K.V.A. Demand	220-Volt Circuit		440-Volt Circuit		550-Volt Circuit	
		Size of Wire	Size of Switch and Fuses	Size of Wire	Size of Switch and Fuses	Size of Wire	Size of Switch and Fuses
10-A6 10-AV	25	No. 4 B. & S.	100 Amp	No 10 B & S	50 Amp.	No. 10 B & S	50 Amp
No. 6	45	No. 1 B & S.	200 Amp	No. 6 B. & S.	100 Amp.	No 6 B. & S	100 Amp.
20-A10 20-AV	50	No. 1 B & S.	200 Amp	No. 6 B. & S	100 Amp.	No. 6 B & S.	100 Amp.
No. 9	55	No. 00 B & S.	350 Amp.	No. 3 B. & S.	175 Amp.	No. 3 B. & S.	150 Amp
10-B	75	No. 000 B & S	400 Amp.	No. 2 B. & S.	175 Amp.	No 3 B. & S.	150 Amp.
40-A2	86	No. 000 B. & S.	400 Amp	No 2 B. & S.	175 Amp	No 3 B. & S	150 Amp
*40-A2	107	No. 0000 B. & S.	600 Amp.	No. 0 B. & S.	250 Amp.	No. 0 B. & S.	200 Amp.

*With oil transformer

power factor; size, 34×60 in. by 79 in. high; weight, 3600 pounds.

For welding tools on these machines the relative thickness of the two parts should be about that shown in Fig. 307. Under ordinary conditions the dimension *A* should be about one-third of *B* in order to have the point of the weld nearest the jaw in contact with the high-speed steel, so that the heating effect

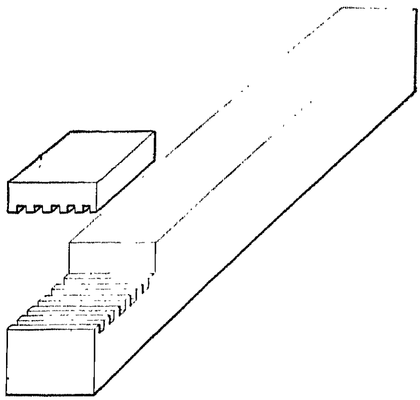


Fig. 308.—Pieces Grooved to Make Better Welds with Less Current.

will be lessened and its fusion point retarded until the low-carbon steel has a chance to heat up properly.

In order to obtain the best results tools wider than 1 in. and with a recess longer than 1½ in. should be grooved as shown in Fig. 308. This reduces the section in actual contact, thereby requiring less current, is easier and quicker to heat and assures a better weld over the entire area of contact.

In order to assist those who have tool or other butt-welding to do some useful data are given in Table XXVI.

In Table XXVII is given the proper size of copper wire to use to connect up the various machines mentioned for tool welding.

CHAPTER XVI

ELECTRIC SEAM WELDING

Seam or line welding is the process of joining two overlapping edges of sheet metal for their entire length without the application of any solder or spelter along the joint. In the Thomson process of lap-seam welding, the heat is produced by passing a large volume of electric current through the edges to be welded by means of a copper roller on one side of the joint and a copper track or horn underneath. In any electrical path, wherever high resistance is interposed, heating will result, and the higher the resistance to the current, the greater will be the heating effect. In the electric lap seam welding machines, the copper roller and horn are good conductors and the joint between the edges of the metal to be welded is the point of highest resistance. On this account it is evident that the greatest heating effect will be at that point. As the roller passes over the joint, heating the stock to a plastic state beneath it, pressure is applied by springs on the roller which forces the two edges together as fast as they are heated. Since 20 B. & S. gage or lighter metal heats very rapidly, the pressure and heating can be effected at the same instant of contact by the roller, and it is possible to weld as fast as 6 in. per second.

The only preparation necessary for seam welding is that the stock must be absolutely clean, that is, free from any traces of rust, scale, grease, or dirt, if a tight, well-appearing joint is desired. If it is not necessary for the joint to be tight, it will not be necessary to have the stock so clean, although heavy scale or rust will obstruct the passage of current, so that little or no heating effect can be secured under these conditions.

In welding sheet brass of 22 to 30 B. & S. gage, to secure a perfect joint the metal should be carefully pickled and washed to remove all traces of grease and tarnish which tend to prevent

the passage of current across the joint of the edges. The metal should be welded soon after pickling, as, no matter how carefully it may be washed, oxidation is always sure to start very shortly after the brass has been removed from the pickling acid.

Steel, to be successfully seam welded, should not have a carbon content of over 0.15 per cent., for a higher carbon steel than this has a tendency to crystallize at the point of weld, due to the rapid cooling of the welded portion from the surrounding cold meta! After welding, the joint will be found to be about one-third thicker than the single thickness of the metal. It is possible, by applying more pressure, to reduce this finished thickness still more, but it wears more on the copper roller to do so.

In welding brass, a soft, annealed metal should be used, for although hard-rolled brass can be welded, it does not force the two edges together very much and the finished joint under these conditions is almost twice the original metal thickness. However, with a soft, annealed brass the finished joint will be not over a third greater than the single metal thickness, and by applying sufficient pressure can be reduced down to be not over 10 per cent. thicker.

The principal advantage of electric seam welding is that no spelter and no flux are required, the metal itself forming its own cohesive properties, which allows great speed in production. The greatest efficiency of a seam welding machine lies not only in its welding qualities but in the use of a suitable jig to properly hold the work. The jig used should be made so as to enable the operator to place or remove the work in the shortest possible time, since the welding itself is very fast compared with any other known method of making a continuous joint.

In order that their seam welding machines may operate in every installation with the highest efficiency possible, the Thomson Electric Welding Co., Lynn, Mass., build them standard only up to a certain point and then design a special holding jig to best fit the work to be done in each individual case. The amount of lap allowed in making lap seam welds is usually about twice the single sheet thickness of the metal.

The operation of a lap seam welding machine is very sim-

ple, once the machine is set for any given piece of work for which a special jig has been built. After placing the piece in the jig and securely locking it there, the operator depresses a foot-treadle which throws in a clutch and starts the copper roller across the work. By the proper setting of adjustable control-stops on the control-rod at the top of the machine, the current is automatically turned on as the roller contacts

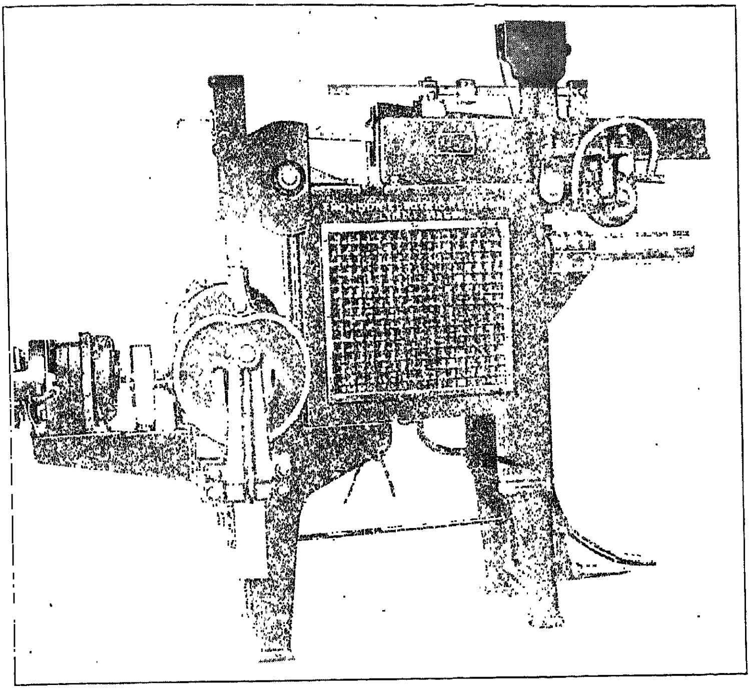


FIG. 309.—Model 306 Lap Seam Welding Machine.

with the overlapping edges of the piece to be welded and is automatically turned off when the roller reaches the end of its stroke; another stop reverses the travel of the roller and brings it back to the starting position. The control-stops may be adjusted to turn the current on or off at any point along the stroke of the roller for doing work with a seam shorter than the maximum capacity of the machine. The roller stroke may be also shortened so that the complete cycle of operation

will be accomplished in the shortest space of time on seams shorter than maximum seam capacity of any machine. In order to keep the copper roller from overheating in action, water is introduced through its bronze bearings on each side. This same water circulation, also passes through the under copper horn or mandrel and then through the cast-copper secondary of the transformer, so that the machine can be operated continually, 24 hours per day if desired, without overheating.

Lap Seam Welding Machines.—The lap seam welding

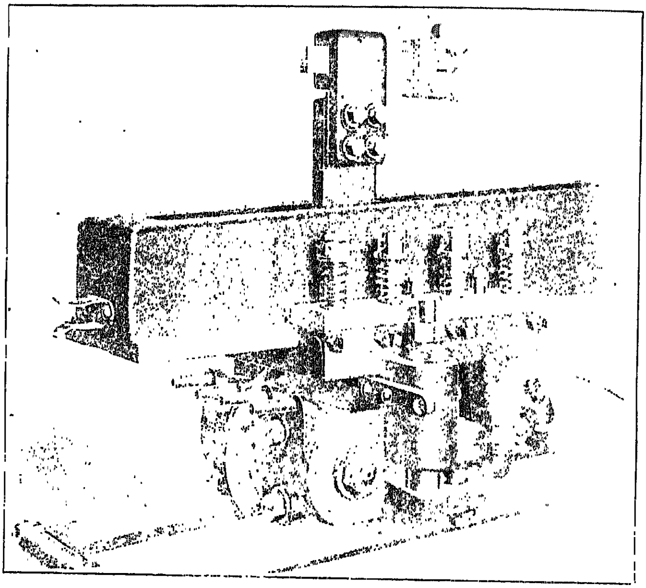


Fig. 310.—Details of Welding Roller Head.

machine, known as Model 306, shown in Fig. 309 will weld a seam 6 in. long in soft iron or steel stock up to 20 gage in thickness, or brass and zinc up to 24 gage thick. This machine will make from 60 to 600 welds per hour, depending on the nature of the work and the quickness with which the pieces can be placed in and removed from the jig. The copper horn is water-cooled and has an inserted copper track on which the work rests. The upper contact consists of a copper roller $6\frac{1}{4}$ in. in diameter, mounted on a knockout shaft sup-

ported in water-cooled bearings. Pressure is exerted on the copper roller by means of a series of springs on each side which are adjustable to give the proper tension for various thicknesses of stock. Current control is automatic through a magnetic wall switch carrying the main current. The latter is controlled from a mechanical switch which is thrown in or out by the action of the roller-carrying mechanism as it starts

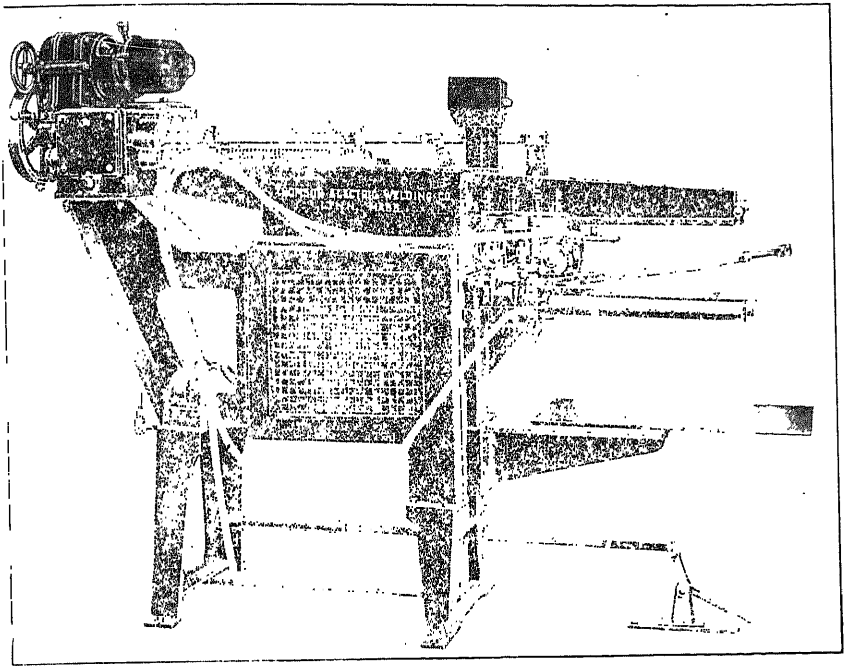


FIG. 311.—Thomson No. 318 Lap Seam Welding Machine.

and completes the stroke for which it is set. Standard windings are for 220-, 440-, and 550-volt, 60-cycle, alternating current. Current variation for different thicknesses and kinds of stock, is effected through a regulator which gives 50 points of voltage regulation. A variable-speed $\frac{1}{2}$-hp. motor gives a wide variation in the speed with which the roller may be fed over the work. The standard ratings for the machine are 15 kw. or 25 kva., with 60 per cent. power factor. This

machine covers 32×96 in. floor space, is 68 in. high and weighs 2750 lb.

A close-up view of the type of roller-carrying head used on all the lap seam welding machines, is shown in Fig. 310. In this view the roller is shown operating between the clamping bars of a special holding jig on the horn. As the roller itself occasionally requires smoothing off around its contacting surface, its bearing has been designed to knock out quickly so

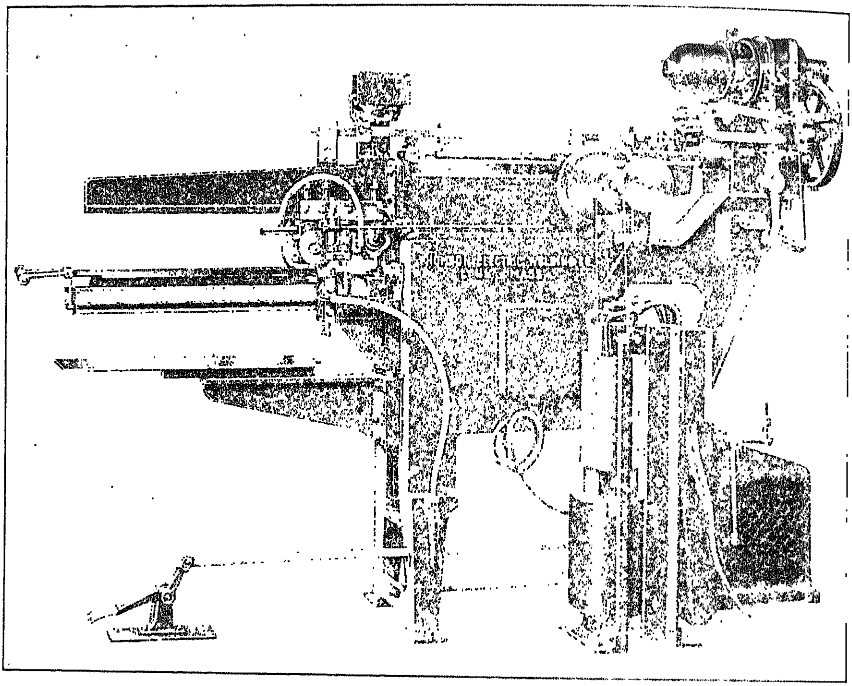


FIG. 312.—Large Size, No. 324, Lap Seam Welding Machine.

that removal and replacement of the roller is very simple and easy to accomplish. The cleaner the stock being welded is kept, the longer a roller will operate without requiring smoothing off, as dirt and scale on the stock cause a slight sparking as the roller passes along, which tends to pit up its contact surface.

The machine shown in Fig. 311, known as Model 318, is a larger and heavier machine than the one previously described

and will weld a lap seam 18 in. long on the same gages of metal quoted. Another very similar but smaller machine (Model 312) is also made for welding seams up to 12 in.

In Fig. 312 is seen a considerably larger machine, Model 324, capable of welding a lap seam up to 24 in. in length. The production is from 30 to 120 welds per hour. The machine covers a floor space of 36×90 in., is 72 in. high, and weighs 3500 lb. All other specifications are the same as given for Fig. 309.

Examples of Holding Jigs.—The machines shown may be fitted with numerous forms of holding jigs from the simple

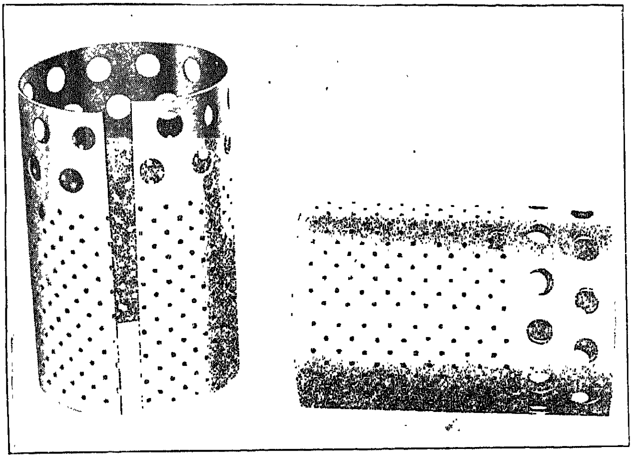


FIG. 313.—Oil Stove Burner Tubes Before and After Welding.

bar clamps shown on the horns in Figs. 311 and 312, to various more complicated forms, some of which may be mounted on the knee below the horn or bolted direct to the face of the machine column.

The small oil stove burner tubes shown in Fig. 313 lend themselves nicely to the seam welding process. Cylindrical pieces such as the shell tubes for automobile mufflers shown in Fig. 314, need a rather elaborate holding jig. A machine fitted up for this work is shown in Fig. 315. To insert a muffler shell into this jig the hinged end is swung outward and downward; the two halves of the holder are spread apart by pressing down on the left-handle treadle; the shell is then

thrust into the holder; the treadle is released, which allows the holder sides to be pressed in by the springs and hug the muffler shell around the horn of the machine, with the edges overlapping enough for the weld; the end gate is then closed and the welding roller started over the seam. The principal function of the gate is to hold the muffler shell square in the jig and prevent it being pushed out by the welding roller.

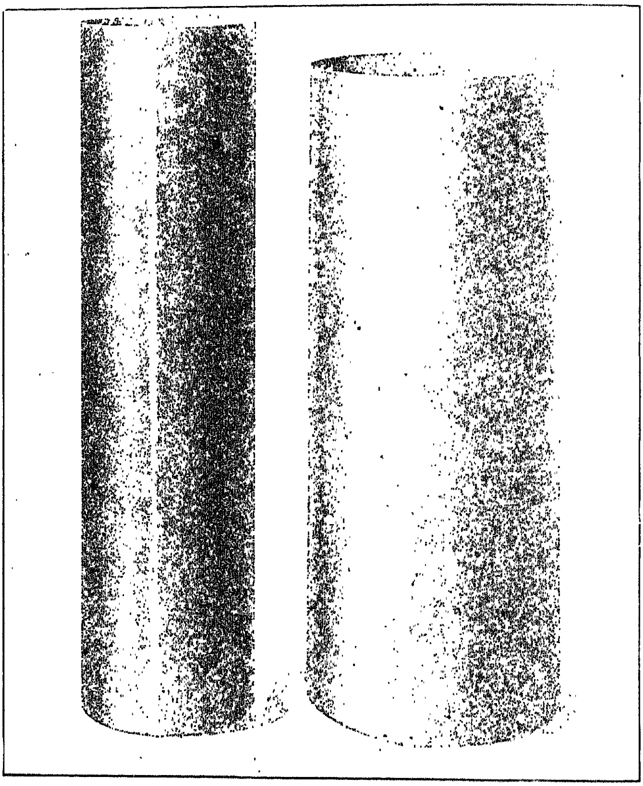


FIG. 314.—Seam Welded Automobile Muffler Tubes.

A jig for holding large cans is shown in Fig. 316. The side clamps of this jig are operated by means of the lever shown at the left. An end gate, shown open, is used in the same way as in the muffler shell jig. Work of this kind is of course much slower than with a smaller jig, yet it is faster than by any other process of closing the seams.

Bucket bodies are held as shown in Fig. 317. The holding jig is made to slide in a channel bolted to the machine knee. The jig is slid back clear of the horn and, with the gate in the flaring end open, the bucket blank is inserted. The gate

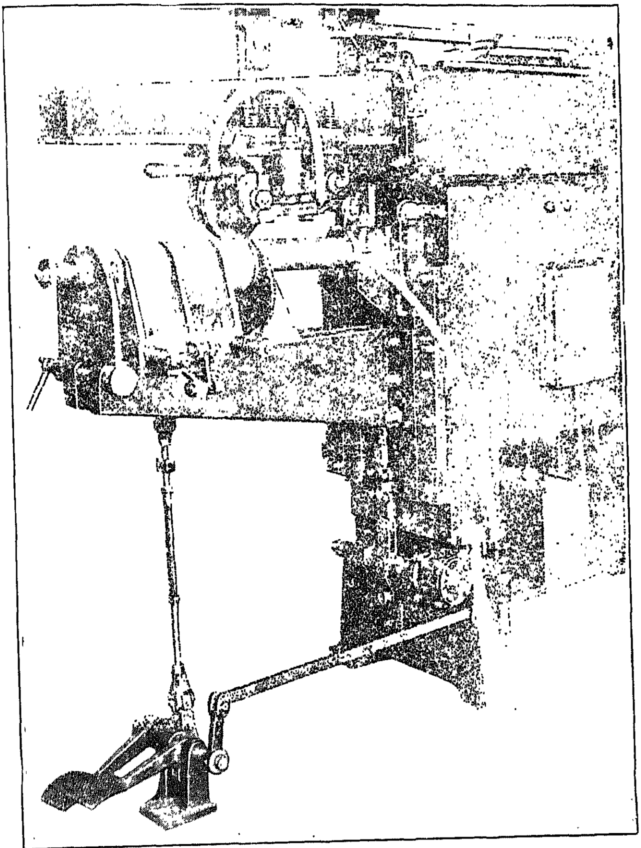


FIG. 315.—Holding Jig for Automobile Muffler Tubes.

is then closed by means of the handle, the jig and work is pushed over the horn to a stop, and the weld is made as usual.

Another application of seam welding, is to use it for welding the ends of strip stock together, end to end, so as to facilitate continuous passage of the strip through the dies of a punch press. A machine fitted up for this work is shown in Fig. 318.

The ends of the two strips to be welded are inserted in the jig from opposite sides and the edges brought together. The pieces are then clamped by means of the two levers shown in front of the jig, which operate eccentrics over the clamping

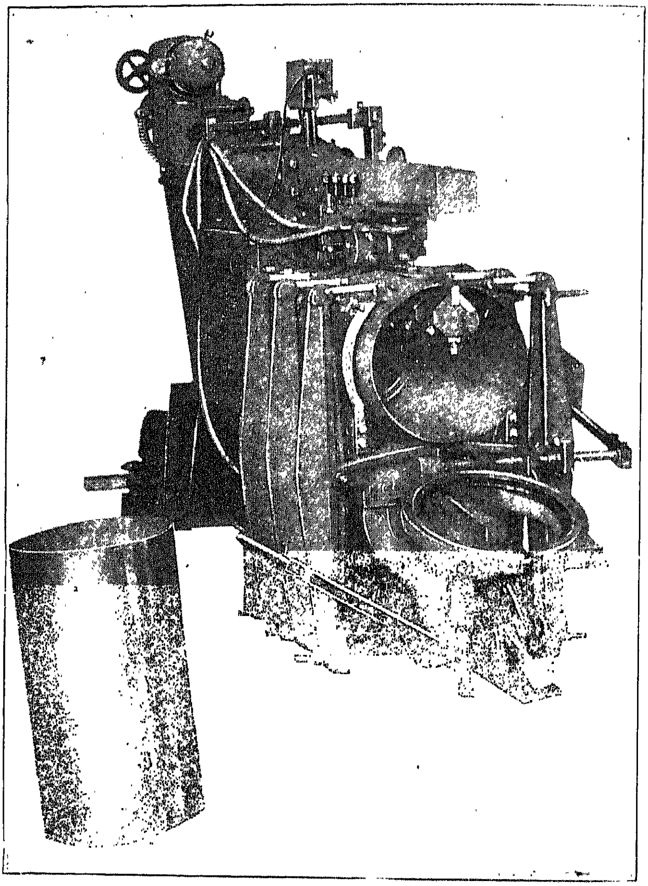


FIG. 316.—Holding Jig for Large Sheet Metal Cans.

plates. The welding roller is then run over the ends as in other work of this kind.

Flange seam welding differs from lap seam welding in that instead of the metal being lapped a slight fin or flange is formed along the edges of the metal parts, the flanges being welded together and practically eliminated in the process. This

class of welding is especially adapted to the manufacture of light gage coffee and teapots spouts or similar work.

A machine built especially for flange seam welding, known

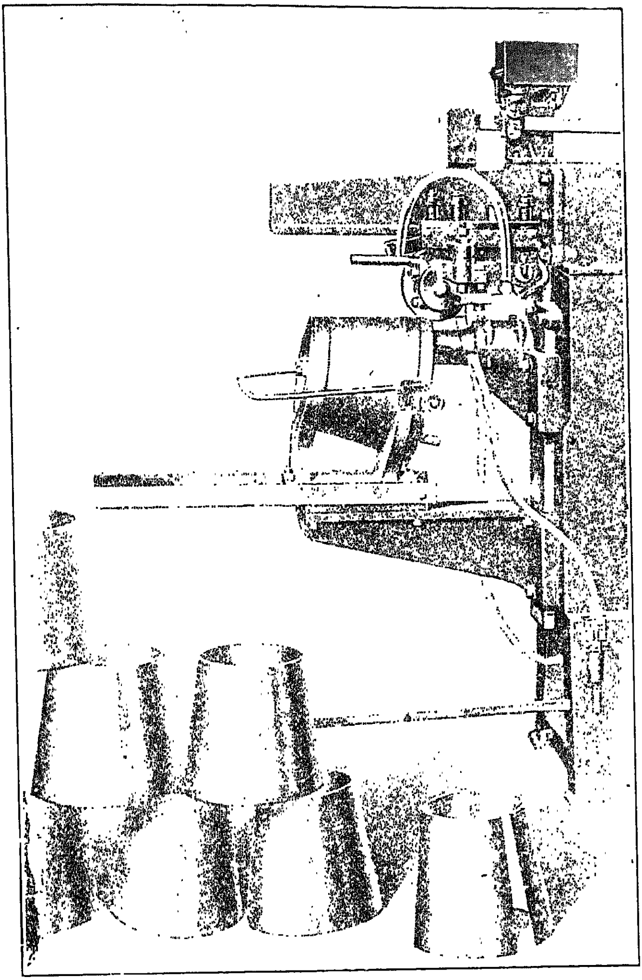


FIG. 317.—Jig for Holding Bucket Bodies.

as Model 26, is shown in Fig. 319. The work being done is the welding of the two halves of teapot spouts. In the operation the two halves of the spout are clamped securely in a special copper jig, Fig. 320, which has been carefully hand-cut to

fit the halves of the spout perfectly on the entire contacting area. The jig is pushed around on the flat copper table, which constitutes the top of the welding machine, so that the seam of the edge to be welded is allowed to ride along the small

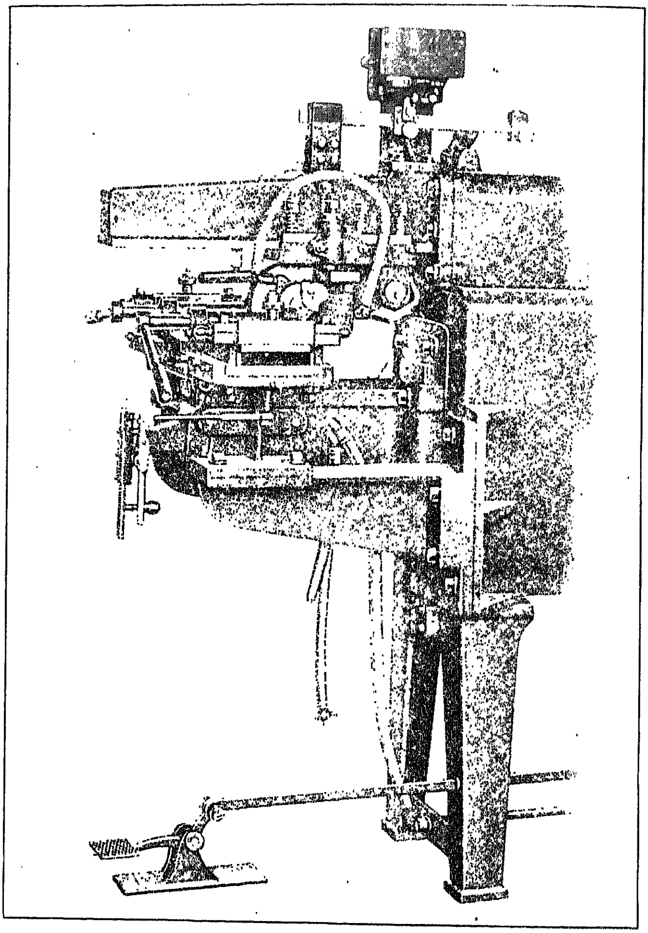


FIG. 318.—Jig for Welding Ends of Metal Strips Together.

power-driven copper roller which is mounted on a vertical shaft, as illustrated in Fig. 321. The halves which are welded by this process must be blanked out by special steel dies to give the correct amount of fin or flange on each edge. This

fin is heated to the plastic stage by contact with the roller and the slight pressure applied not only forces the metal of the two fins to cohere but also forces the projection into a level with the outer surface of the spout, thus giving a finished job direct from the welder which is smooth enough without

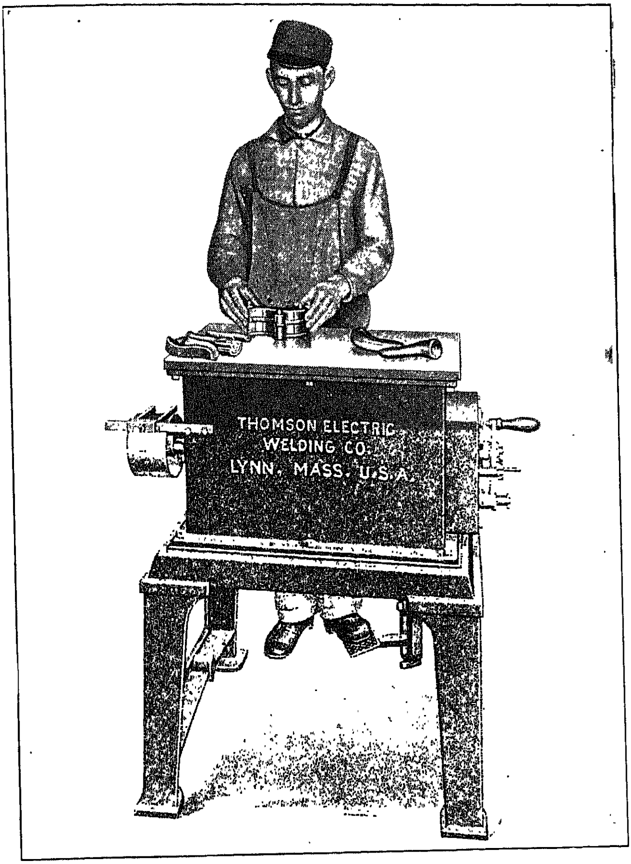


FIG. 319.—Machine for Flange Seam Welding.

any grinding to be ready for the enamelling or agate-coating process.

The secret of success of this work lies wholly in the proper preparation of not only the copper holding-dies, but also the steel flanging and forming dies. A finished spout, just as it

TABLE XXVIII.—COMPARATIVE THICKNESS AND APPROXIMATE CURRENT CONSUMPTION FOR 6-IN. SEAM.

THICKNESS OF SINGLE SHEET				K.W.H. CONSUMED PER 1000 WELDS	COST PER 1000 WELDS @ 1c PER K.W.H.*	THICKNESS OF SINGLE SHEET				K.W.H. CONSUMED PER 1000 WELDS	COST PER 1000 WELDS @ 1c PER K.W.H.*
Decimals of inch	Decimals of Millimeter	B. & S. Std. Gauge	Birmingham Gauge			Decimals of inch	Decimals of Millimeter	B. & S. Std. Gauge	Birmingham Gauge		
.00394	10			.075	.0007	.02			25	.78	.0078
.00787	.2			.175	.0017	.0201		24		.78	.0078
.01002		30		.25	.0025	.022			24	.95	.0097
.01126		29		.3	.003	.02257		23		.975	.0097
.01181	.3			.35	.0035	.02362	.6			1.05	.0105
.012			30	.35	.0035	.025			23	1.175	.0117
.01264		28		.375	.0037	.02535		22		1.257	.0126
.013			29	.4	.004	.02756	7			1.35	.0135
.014			28	.45	.0045	.028			22	1.4	.014
.01419		27		.46	.0046	.02846		21		1.425	.0142
.01575	.4			.525	.0052	.03149	8			1.65	.0165
.01594		26		.55	.0055	.03196		20		1.7	.017
.016			27	.56	.0056	.032			21	1.7	.017
.0179		25		.675	.0067	.035			20	1.925	.0192
.018			26	.68	.0068	.03543	9			1.95	.0195
.01968	.5			.75	.0075	.03589		19		2.	.02

* Multiply these values by the rate you are paying per K. W. Hour for current, to determine what the cost per 1000 welds for any size would be at your plant.

TABLE XXIX.—SIZE OF COPPER WIRE TO USE TO CONNECT UP THE WELDING MACHINE.

(Where the machine is not over 150 ft. from source of supply.)

Type Machine	K.V.A. Demand	220-Volt Circuit		440-Volt Circuit		550-Volt Circuit	
		Size of Wire	Size of Switch and Fuses	Size of Wire	Size of Switch and Fuses	Size of Wire	Size of Switch and Fuses
No. 26 No. 306	8	No. 12 B. & S.	35 Amp.	No. 14 B. & S.	20 Amp.	No. 14 B. & S.	15 Amp.
No. 312 No. 318 No. 324	25	No. 4 B. & S.	100 Amp.	No. 10 B. & S.	50 Amp.	No. 10 B. & S.	50 Amp.

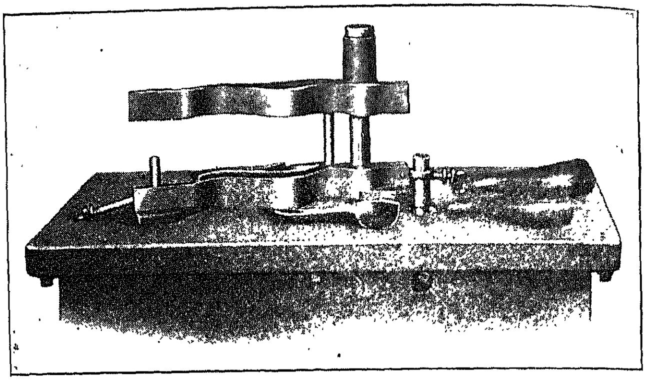


FIG. 320.—Jig for Holding Teapot Spouts for Welding.

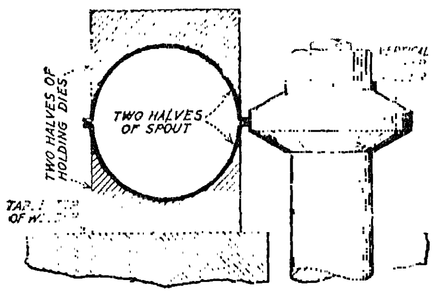


FIG. 321.—Diagram of Flange Seam Welding Operation.

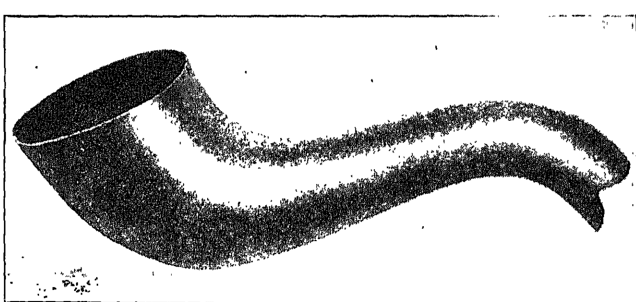


FIG. 322.—A Finish Welded Teapot Spout.

comes from the welding machine, is shown in Fig. 322. The welded seam is barely visible.

In order to assist those who have welding jobs to do, to calculate the current cost on various jobs, Table XXVIII is given. This table shows the approximate current consumption, and multiplying the rate given by the local rate charged, the cost of 1000 welds can be easily ascertained.

Table XXIX is very convenient for ascertaining the size of copper wire needed to connect the different machines mentioned to the main source of current supply.

CHAPTER XVII

MAKING PROPER RATES FOR ELECTRIC WELDING AND THE STRENGTH OF WELDS

The uncertainty which seems to exist regarding electric welding rates among central-station interests, says S. I. Oesterreicher in *Electrical World*, is no doubt due to the indifference of the welding industry, which during a long period in the past did not assist those affected by the rates as much as its unquestionable duty would have suggested.

While welding installations of only comparatively small sizes had to be considered—say from 25 to 100 kva.—no great harm was done by such tactics to either interest. However, with the installation of large equipments and the operation of large unit welding machines, central stations suddenly experienced disturbances upon their lines and in their stations, which were anticipated but partly and were blamed entirely upon the welding equipment. Thus, to protect themselves, central-station interests launched into a partially retroactive policy, greatly to the detriment of the welding industry as a whole.

Since welding installations of several thousand kva. capacity are not unusual, it is proper that all points of doubt should be considered as broadly and fairly as possible, and a far-reaching co-operative policy inaugurated. The revenue from such large installations may easily reach several thousand dollars a month. It is therefore obvious that, from a purely commercial standpoint, a welding load is a very desirable constant source of income to the central station.

Looking at the reverse side, it should be recalled that central-station engineers, on account of past sad experiences, had jumped to the following conclusions:

1. That a welding installation is a very unreliable metering proposition.

2. That it has a poor load factor.

3. It has a constantly fluctuating load varying between extreme limits, and

4. It has a bad power factor.

The first important point is, no doubt, the metering. The time-honored opinion on one side that, due to the short period involved, an integrating wattmeter does not respond quickly enough, is contradicted by the claim on the other side that the deceleration of the meter disk compensates for the lagging acceleration. As far as the writer is aware, not the slightest positive proof has been offered to support either contention. Considering for instance a 200-volt, 300-amp., single-phase, two-wire wattmeter, whose disk at full load makes 25 r.p.m., and assuming the total energy consumption to be integrated within 0.2 second, it will be found that to register correctly the meter disk has to travel about 0.08 of a revolution. It is scarcely possible that by merely looking upon a meter disk any one could guess within 100 per cent the actual travel during such a short time interval. A stop watch will scarcely be of any assistance; neither will a cycle recorder with an ammeter and voltmeter check be of any value, since no instrument is of such absolute dead beat as to come to rest from no load to full load within 0.2 second. Such methods therefore are of no value in ascertaining the behavior of a wattmeter under sudden intermittent heavy loads.

The next step of the metering proposition was to take the rated energy consumption of the welding machine as given by the manufacturer, assume a certain load factor, calculate from these data the energy consumption, correct for the power factor and check the answer periodically on the meter dial. The result obtained on the meter was usually a constantly varying, lower energy consumption than calculated, and no doubt this was the cause of the great distrust of the meter. This method is worse than no check at all, and it is so for the following reasons:

1. The energy consumption at a welder depends upon the welding area of the metal, but is not a proportionate variable. That is, all other factors being the same, two square inches of a certain weld do not consume twice as much energy as one square inch does. Fig. 323 shows this fact plainly. It

is also of common knowledge that on a spot welder the area of the weld varies from weld to weld just as much as the electrode contact area does. Assuming an electrode at the start as $^3/_{16}$ in. diameter at the tip, after about 200 welds it might be anything from $\frac{1}{4}$ in. to $^5/_{16}$ in. diameter, thus gradually increasing its contact area anywhere from 75 per cent to 175 per cent.

2. On butt welders the energy consumption does not depend

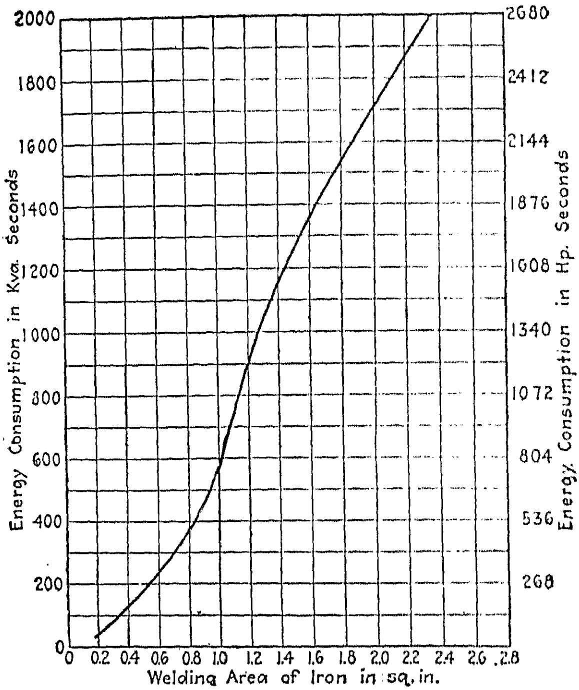


FIG. 323.—Energy Consumption of Resistance Welding for Commercial Grades of Sheet Iron.

upon the size of the weld alone, but also upon the clamping distances. Fig. 324 gives some information about the influence of variable clamping distances upon the energy consumption of welding machines. On a butt welder, the clamping distances increase with the gradual wear of the electrode; thus the above spot welder conditions are duplicated on butt welders also.

3. If no compensation is made to vary the impressed emf.

of the welder—and this is never done—then the time must vary from weld to weld according to the condition of the electrode. If the time is changing constantly, the assumed load factor changes correspondingly; thus there are three constantly changing factors in the estimated energy consumptions, beyond any reasonable approximation of the actual facts.

A more reliable method would be a periodic oscillograph test, but this method is rather complicated and expensive and could be done only by large central stations which have both the equipment and the trained personnel for such work.

Such tests, once they are made for certain types of welders

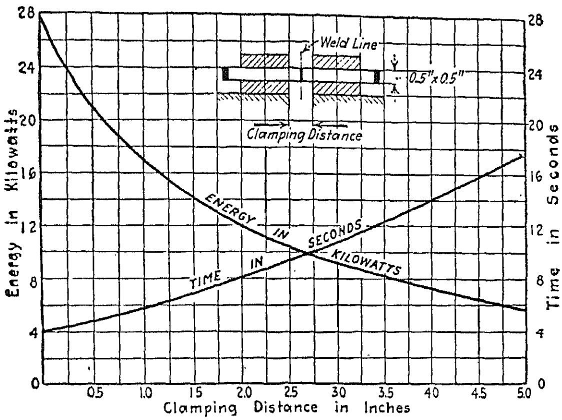


FIG. 324.—Effect of Clamping Distance Between Electrodes Upon Time and Energy Demand. Area, 0.25 Sq. In.

and work, will give excellent data from which to check the actual behavior of the standard type of wattmeter. If such comparisons are made, it will be found that the integrated energy consumption of the wattmeter will be larger than the oscillograph test indicates. It is not intended to claim that the wattmeter registers "fast." Laboratory tests are usually made by skilled men, who before the test carefully ascertained all important factors entering into the test, as area of weld, condition of electrodes, welder, emf., cleanliness of material, etc., whereas under normal operating conditions almost no attention is paid by the operator to these considerations. In fact, if the operator works on a piecework or bonus basis, he will conceal as much as possible all discrepancies which have

a tendency even temporarily to curtail his earnings. The result of his policy has a very important effect upon the wattmeter.

Summing up the metering proposition and speaking from experience on large welding installations with capacities over 250,000 sq. in. of welding per month, where ten to fifteen butt welding machines are constantly thrown on or off the supply circuit, it is safe to claim that in such installations the standard alternating-current integrating wattmeter is on the job.

The Load Factor.—The present-day tendency in resistance welding practice is to perform the weld as quickly as possible without injury to the metal, but fast enough to prevent imperfection at the weld. Having in mind large welders with 5 to 15 sq. in. weld capacities, this tendency will give a unit load factor not much over 10 per cent per welder. From the central-station viewpoint, this factor is certainly very low and undesirable.

However, two important circumstances alter the condition considerably. The first point is that in large installations one large welder will not suffice to do all the required work, therefore several will have to be installed. Owing to the big energy demands these large welders never operate simultaneously. While one welds the next is cleaned, the third is prepared, the fourth is waiting for the signal to weld, etc.; thus the load factor of the installation as a whole is considerably over 10 per cent and nearer to 20 per cent. Another natural circumstance of large installations is the fact that not all work requires large welders. There are usually ten to fifteen smaller welders installed, of which 30 per cent might work intermittently with the larger welders. Thus it will be seen that the load factor is bad only in small installations connected to small central stations, while large installations, which necessarily must receive their supply of energy from comparatively larger central plants, have rather a good aggregate load factor, reaching well up to 25 to 30 per cent.

Another point for consideration is the fact that, owing to its temperature, large work cannot be handled immediately after welding. The work must cool off before additional operations can be performed upon it. The cooling takes some time. In several instances it was found desirable to shift the working hours of the welding crew several hours ahead or behind the

working hours of the rest of a factory, for the sole reason that there should be on hand sufficient cool welded work for the successive manufacturing steps. If this time-shifting is selected to coincide with the low-point period of the load factor of a central station, then there results an actual all-around improvement. For this the welding installation should be entitled to a certain proportionate consideration.

Maximum Demand.—Owing to the instantaneous severity of a welding load, demand upon a supply station seems to be of considerable importance. However, the shifting of a load factor toward an off-load period, as described, will certainly take the severest effects off the system. Under such conditions regulation of the supply system suffers only in small plants, and only in places where lighting and power loads are fed from the same mains

But large welding installations are usually direct-connected through transformer banks to the station buses, where the fluctuating character of the welding load will be almost negligible and certainly will not affect the regulation of a system in a degree commensurate with the size of the connected welding installation. Of course in all these discussions it is assumed that the station apparatus, transformers and supply feeders are properly selected, with equipment properly calculated to fit the particular welding load. In the past this has not always been the case, and this is one of the causes of so many different maximum demand charges.

The ratio which the maximum demand should bear to the connected load will always remain a local issue between producer and consumer. The ratio should, however, be made to depend on the average kilovolt-ampere energy demand of all the welders (and not on their rated capacities as given by the manufacturer) and of the rated capacity of the primary supply installation. If the welding customer bears a part of the installation charges caused by larger transformers and larger supply mains, he should benefit by the resultant mutual advantages. However, no demand charge should be based upon a mixed welding and motor load supplied from a common primary installation. The importance of this claim will be more evident if it is stated that by separating a certain mixed welding and motor circuit, and by installing an additional

100-kw. equipment, the maximum-demand charge in a single supply circuit in one month was reduced over $200.

To be sure that no more disturbing overloads are thrown upon the line than have been contracted for, overload relays, time clocks and maximum-demand indicators will be found sufficiently reliable for all honest purposes on both sides of the controversy.

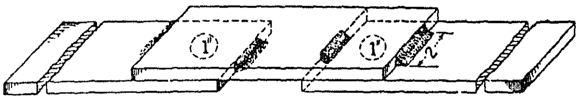
Proper grouping of the single-phase welding loads upon a three-phase supply system will give perfect satisfaction in almost all installations but those of small size.

Power Factor.—So much has been said and so much worry caused about the poor power factor of a welding installation that it is now universally accepted that the power factor is bad, and nothing further is done about it. The outstanding feature about this condition is that the central stations, in a most unfortunate moment, decided to "penalize" the power factor. It is not the charge for the condition, but the adoption of the word for the charge, which makes the customer balk and is the cause of no end of distrust toward the welding machine. The word "penalty" conveys to the lay mind the impression that a poor power factor exists only with welding installations, and naturally the conclusions are not flattering for the welding equipment.

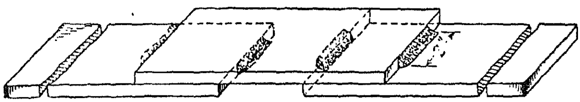
No attempt is made here to describe the well-known methods of improving the power factor of a welding installation with synchronous apparatus. The adoption of such methods is more of a commercial than an engineering problem. Upon investigation it will be found that, with few exceptions, it is cheaper to pay for the poor power factor than to invest in additional apparatus. However, the average power plant usually has, besides a welding installation, a number of other consumers, the effects of whose poor power factor are felt in considerable measure at the generators. If all such sources are investigated and segregated upon one common bus, together with a welding load, it might be found that either a synchronous or static apparatus would more than pay for itself, if installed at the proper place.

If this fact is explained to a welding customer, there can be no doubt that he will be only too eager to bear a certain proportion of the investment for a special apparatus and thus

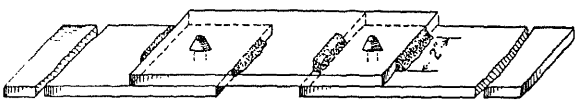
secure for himself a better rate for the consumed energy. With proper co-operation between the central station and the welding customer on all these points of mutual interest, much misunderstanding and distrust could be eliminated, benefiting all parties concerned in the welding industry.



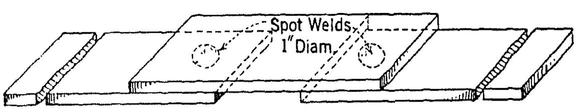
FILLET AND SPOT WELDED



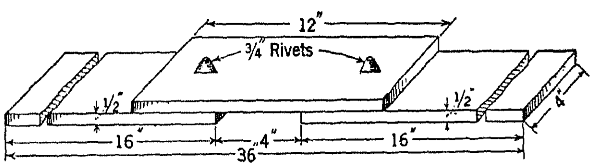
FILLET WELDED



RIVETED AND FILLET WELDED



SPOT WELDED



RIVETED JOINT

FIG. 325.—Welded and Riveted Joints.

Strength of Resistance Welds.—In some of its applications, spot welding affords a method of preliminary joining ship hull plates, after which the required additional strength is obtained by arc welding. The Welding Research Sub-Committee made some progress in comparing combined spot and

arc welds, and combined rivet and arc welds with riveted, spot-welded and arc-welded joints. It is not a question in such an investigation, of spot versus arc welding, but of spot and arc welding.

According to Hobart, test specimens are made up of the following combinations:

(a) Spot and fillet welds (two samples made)

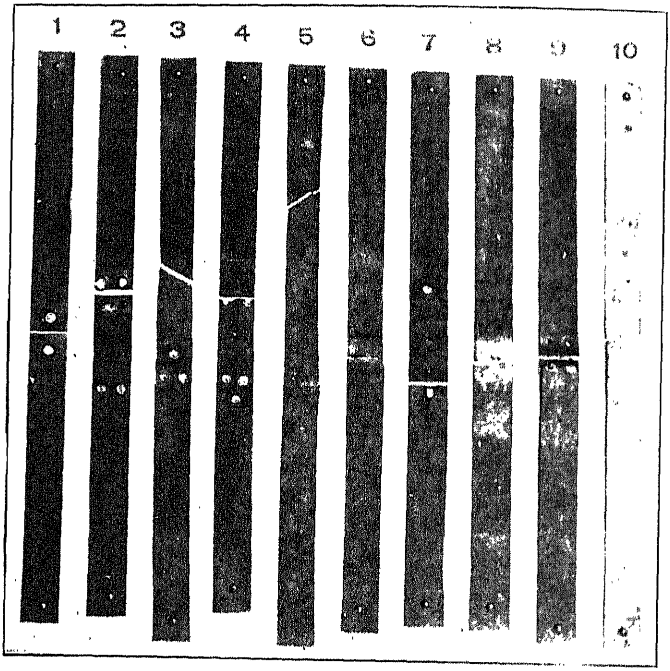


FIG. 326.—Spot-Welding Tests on Hoop Iron.

(b) Fillet welds, made by welding fillets about two inches in length at the ends of overlapping plates (two samples made)

(c) Rivet and fillet welds (one sample made)

(d) Spot welds, made by welding two spots approximately one inch in diameter, on the plates (two samples made)

(e) Riveted joint, made by riveting a $\frac{1}{2}\times4\times12$ in. plate with two plates $\frac{1}{2}\times4\times16$ in., using two $\frac{3}{4}$ in. rivets and a four inch plate lap (one sample made)

The way these plates were fastened is illustrated in Fig. 325. The results of the tests were as follows:

(a) Spot and fillet weld..................ultimate load........50,350 lb.
(b) Fillet welds ....ultimate load........37,000 lb.
(c) Rivet and fillet welds...............ultimate load........35,000 lb.
(d) Spot welds ....ultimate load........28,000 lb.
(e) Riveted joint ....ultimate load........13,000 lb.

Spot-Welding Tests on Hoop Iron.—The Thomson Co. made up ten samples of spot-welded, riveted, butt-welded and plain pieces of hoop iron, and had them tested in the Lunkenheimer laboratory. The pieces after testing are shown in Fig. 326.

The results were as follows:

No. 1. Spot-welded in one place—broke at weld at 1,625 pounds.
No. 2. Spot-welded in two places, also two rivets—broke at rivets at 1,555 pounds.
No. 3. Spot-welded in three places—broke outside weld at 2,715 pounds. (Notice elongation of metal.)
No. 4. Spot-welded in three places, also three rivets—broke at rivets at 2,055 pounds.
No. 5. Solid lap-weld—broke outside weld at 2,720 pounds.
No. 6. Butt-welded—broke at weld at 2,555 pounds.
No. 7. Spot-welded in one place, and riveted once—broke at rivet at 990 pounds.
No. 8. Solid lap-weld—broke at weld at 2,425 pounds.
No. 9. Spot-welded in two places—broke at weld at 2,275 pounds.
No. 10. Plain piece of hoop iron, not welded—pulled apart at 2,690 pounds.

Taking the average of the breaking points of the three pieces, 3, 5 and 10, that broke in the pieces themselves, we get approximately 2700 lb. as the strength of the hoop iron. This furnishes a basis for percentage calculations if such are desired. By grouping six of the tests, we get the following results for comparative purposes:

Test No. 1. One Spot-weld: broke at 1,625 pounds.
Test No. 7. One Rivet: broke at 990 pounds.
The weld stood over 60 per cent more than the rivets.
Test No. 9. Two Spot-Welds: broke at 2,275 pounds.
Test No. 2. Two Rivets: broke at 1,555 pounds.
The weld stood over 60 per cent more than the rivets.
Test No. 3. Three Spot-Welds: broke outside weld at 2,715 pounds.
Test No. 4. Three Rivets: tore apart at 2,055 pounds.

Strength of Spot-Welded Holes.—It sometimes happens that a hole will by mistake be punched in a plate where it is not needed. The spot welder can be used to plug such holes and make the plate as strong as, or stronger than, it was originally. It is first necessary to make a plug of the same material as the plate which will fit in the hole and which is slightly longer than the plate is thick. The length required will depend on the snugness of the fit of the plug in the hole; there should be enough metal in the plug to a little more than completely fill the hole. The plate is placed in the welder with the hole which is to be filled centered between the electrodes, the plug is placed in the hole, the electrodes brought together upon it,

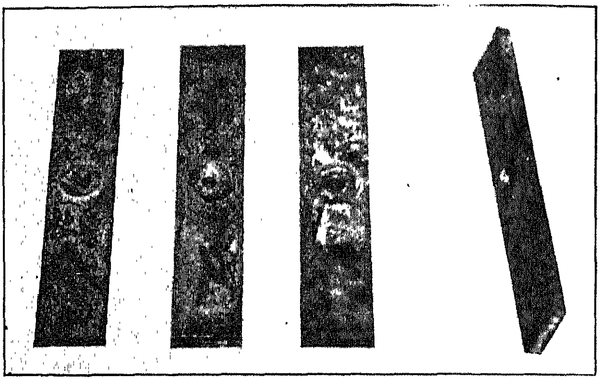


FIG. 327.—Sample Plates with Holes Plugged by Spot-Welding. At the Right Is Shown a Plate with Plug in Place Previous to Welding.

and upon the application of pressure and current the plug will soften, fill the hole, and weld to the plate.

Fig. 327 shows, at the extreme right, a piece of $\frac{1}{2}$-in. plate with a punched hole which is to be plugged, and the plug in place previous to welding. The three pieces at the left of the photograph have the plugs welded in place. A fact which the illustration does not bring out very clearly is that the surface, after the plug is fused in, is practically as smooth as the remainder of the plate, the maximum difference in thickness between the plugged portion and the remainder of the plate being not more than $^1/_{32}$ in. on a $\frac{1}{2}$-in. plate.

That there is a real and complete weld between the plug and the plate is shown by Fig. 328. The four samples illus-

trated were placed in a testing machine and broken by longitudinal pull, with the interesting result that not one of the three plugged plates broke through the weld. The sample at the right was broken to give an indication of the strength of the samples after punching and before welding. Two sam-

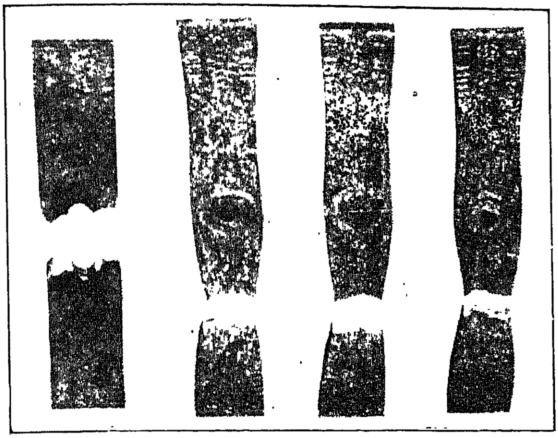


FIG. 328.—Plates Shown in Fig. 327 After Pulling in the Testing Machine. Note That All Welded Plates Broke Outside the Weld.

TABLE XXX.

No. of Sample	Description of Sample	Section In.	Tensile Strength Lb.	Location of Fracture
1	Punched $\frac{9}{16}$-in. diameter hole and plugged by welding	2 by ½	59,320	Outside weld
2	Punched $\frac{9}{16}$-in. diameter hole and plugged by welding	2 by ½	59,320	Outside weld
3	Punched $\frac{9}{16}$-in. diameter hole and plugged by welding	2 by ½	59,350	Outside weld
4	Punched $\frac{9}{16}$-in. diameter hole but not plugged	2 by ½	31,590	Through hole
5	Original bar, not punched	2 by ½	59,230	Through center
6	Original bar, not punched	2 by ½	59,000	Through center

ples (not shown) from the same bar but without the punched holes were pulled to find the original strength of the material. The results are given in Table XXX.

It is interesting to note that the average of the breaking point of the three samples punched and plugged was 59,330 lb., whereas the average for the two samples not punched was 59,115 lb., or 115 lb. less. This proves that there was no weakening of the surrounding plate, due to the weld. That the ductility of the welded section was somewhat decreased is shown by the photographs of the samples after pulling.

The actual welding time required for plugging a hole in a plate is from five to ten seconds. Of course, it is necessary to have a plug of the proper size, but a variety of plugs, of all the standard rivet hole diameters and of lengths suitable for the various thicknesses of plates, could be made up and

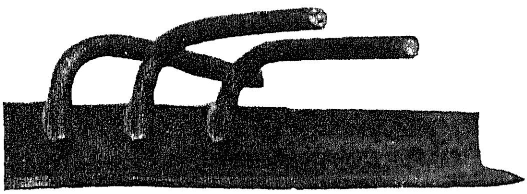


Fig. 329.—Straight Rods Spot-welded to Angle Iron and then Bent by Hammer Blows, the Angle Being Supported only by the Unwelded Flange.

kept in stock in the yard. The method described should prove a valuable means of salvaging material which otherwise might have to be scrapped.

Strength of Rods Mash-Welded to Angle Iron.—While no figures are available, the illustration Fig. 329 will give an idea of the strength of welds where rods are mash-welded to angle iron or plate. Three straight iron rods were welded to an angle iron and then hammered over with a sledge, as shown. This is a very severe test of a weld.

Strength of Electric Resistance Butt-Welds.—According to Kent, tests of electric resistance butt-welded iron bars resulted as follows:

32 tests, solid iron bars, average..........52,444 lb.
17 tests, electric butt-welds, average......46,836 lb.

This is an efficiency of 89.1%.

Presumably the welds were turned to the size of the bars, although Kent does not say so.

In a number of tests on draw-bench mandrels the following results were obtained. The mandrels consisted of one piece of $\frac{5}{8}$ in. dia., 30-40 point carbon steel, welded on to another piece of $\frac{5}{8}$ dia., 110 point carbon Carnegie electric tool steel No. 4. The low carbon ends were drilled and threaded to receive the stud of the bench rod, and the high carbon ends were upset, machined, and used as working heads. Six samples of each kind of steel were prepared and sent to the Thomson Electric Welding Co. of Lynn, Mass., to be welded.

After welding the mandrels were subjected to the following heat treatments and operations:

1. Head-end annealed after upsetting.
2. Head-end machined, and hardened by quenching in water.
3. Mandrels worked on draw benches until worn out or broken.
4. Entire length of mandrels heated to 1450° F. and cooled in air.
5. Mandrels subjected to tensile test to destruction.

Mandrel No. 1.—Pulled 5125 ft. of $1 \times .112$ in. to $\frac{7}{8} \times .107$ in., 17 point carbon. Rather heavy pull. Broke stud once, and used again after replacing same. Pulled to destruction in standard testing machine, and failed $2\frac{1}{2}$ in. below weld on low carbon end, at a stress of 59,000 lb. per sq. in. Weld stronger than low carbon round.

Mandrel No. 2.—Pulled 3360 ft, of $1^{3}/_{16} \times .46$ in. to $^{3}/_{4} \times .38$ in., 17 point carbon. Not badly worn at end of load. Pulled to destruction in testing machine, and failed 1 in. below weld on low carbon end, at a stress of 58,800 lb. per sq. in. Weld stronger than round of 30-40 point carbon of same cross-section.

Mandrel No. 3.—Pulled 2400 ft. of $1 \times .112$ in. to $\frac{7}{8} \times .107$ in., 17 point carbon. Broke at stud and replaced by another mandrel. Pulled to destruction in testing machine, and failed on weld at stress of 58,000 lb. per sq. in. Weld 98% efficient, referred to mandrel No. 1.

Mandrel No. 4.—Pulled 2250 feet of $1^{3}/_{4} \times .200$ in. to $1^{1}/_{16} \times .200$ in., 17 point carbon. In good shape at end of load.

Pulled to destruction in testing machine and failed on weld, at a stress of 56,900 lb. per sq. in. Weld 96% efficient, referred to mandrel No. 1.

Mandrel No. 5.—Pulled 402 ft. of $1 \times .112$ in. to $\frac{7}{8} \times .108$ in., 17 point carbon. Broke off at stud of rod, tube being unduly oversize. Pulled to destruction in testing machine, and failed on weld at a stress of 53,700 lb. per sq. in. Weld 91% efficient, referred to mandrel No. 1.

Mandrel No. 6.—Mandrel broken at thread on first tube. Tube over-size. Mandrel lost.

Conclusion.—Out of five mandrels subjected to a tensile test to destruction after being worked on the benches, two show that the weld is stronger than the 30-40 point carbon round solid rod, and the other four showed efficiency of 91% to 98%, referred to 59,000 lb. per sq. in. The maximum required efficiency is not over 70%. Therefore the mandrels passed all requirements for strength and service.

Strength of High Carbon Steel Welds.—In order to throw some light upon the chemical and physical changes induced by the welding process, pieces of 0.97 per cent carbon drill steel, of $\frac{5}{8}$ in. diameter, were studied after butt welding, writes E. E. Thum in *Chemical and Metallurgical Engineering*, Sept. 15, 1918. Test pieces of the original stock and of both annealed and unannealed welds were made by mounting in a lathe, removing the excess metal of the fin, and then turning or grinding a short length of the bar accurately to a diameter of $\frac{1}{2}$ in., with the weld in the center of the turned portion. In the unannealed welds, the turned portion was but $\frac{1}{2}$ in. in length in order that the failure would be forced to occur within the portion of the bar altered in constitution by the welding heat. Tension tests of the unannealed welds showed, in all cases, a failure with little or no necking occurring at the end of the turned portion—that is to say, farthest from the weld and in the softest portion of the test piece. The strength this developed was much higher than even the strength of the original steel, and it is clearly evident that all parts of this weld have a higher ultimate strength than the original bar. The average results of the tension tests follow:

	Ultimate Strength Lb. per Sq. In.	Contraction in Area, Per Cent	Elongation in ½ In. Per cent
Original tool steel....................	114,100	12	10
Unannealed weld	158,700	2	3
Weld annealed at 750° C. (1382° F.)..	100,800	24	16

In the annealed bars failure always occurred at the weld, accompanied by considerable necking, strictly limited to the close proximity of the point of failure.

The results of a series of tests on butt- and spot-welds made by G. A. Hughes, electrical engineer of the Truscon Steel Company, Youngstown, Ohio, were reported as follows:

TESTS MADE ON BARS OF SOFT STEEL, 1 IN. SQ., BUTT-WELDED AND MACHINED TO THE SIZE OF THE BAR.

Test No.	Volts	Amps.	Kw.	Power Factor
1	220	220	40.	91
2	220	220	40.	91
3	220	210	39.	84
4	218	210	39.5	86
5	220	210	39.	84

All tension tests were pulled at a speed of ½ in. per min. Nos. 1, 2 and 3 were pulled, while Nos. 4 and 5, were sheared. On the different tests, No. 1 failed in the weld at 48,800 lb.; No. 2 failed in the weld at 52,300 lb.; No. 3 failed back of the weld at 50,100 lb.; No. 4 failed at 51,500 lb. and No. 5 at 50,300 lb.

These tests indicate that the ultimate shearing strength of such a weld closely approaches the ultimate tensile strength.

Pieces of soft steel, $^3/_{16}$ in. thick and 5 in. wide, with an ultimate tensile strength of 56,150 lb., were butt-welded and pulled with the following results:

Test No.	Manner of Failure	Lb.	Per Cent
1	½ in plate and ½ in weld	51,000	91
2	In plate just back of weld	52,000	93
3	" " " " " "	53,400	95
4	" " " " " "	52,000	93
5	" " " " " "	46,100	82
6	" " " " " "	51,900	93

On six samples of spot-welded single lap-joint sheets of 14 gage steel, 3 in. wide, welded with a $^5/_{16}$ in. spot, the average at which the welds pulled out, was 4480 lb.

The ultimate tensile strength of a piece of plate of 14 gage, was 64,500 per sq. in. The ultimate shearing load per weld (two spots with an area of 0.0742 sq. in. each) averaged 8942 lb. Approximate total welded area, 0.1484 sq. in. This gives an ultimate shearing strength for 1 sq. in. of weld, of about 60,200 lb. On steel 3/8 in. thick and 2 in. wide, welded with a spot having an area, measured with a planimeter, of 0.476 sq. in., the failure under pull was at 34,650 lb. Examination of the welds showed them to be under both a tensile and a shearing action. A piece of the same steel tested for ultimate strength, failed at 66,800 lb. per sq. in. This shows that the weld was stronger than the original metal.

The final conclusions drawn by Mr. Hughes from his tests, are that, in general, the ultimate tensile strength of a properly made butt- or spot-weld, is about 93 per cent of that of the parent metal, and the ultimate shearing strength of a properly made butt- or spot-weld is also about 93 per cent.

ELEMENTARY ELECTRICAL INFORMATION

What is a Volt?—This is a term used to represent the pressure of electrical energy. In steam we would say a boiler maintains a pressure of 100 pounds. This term relates to pressure only regardless of quantity, just as the steam pressure of a boiler has nothing to do with its capacity.

What is an Ampere?—This term is used to represent the quantity of current. In the case of steam or water we speak of carrying capacity of a pipe in cubic feet, while in electricity the carrying capacity of a wire is given in amperes.

What is a Watt?—This is the electrical unit of power and equals volts$\times$amperes. One mechanical horsepower is the equivalent of 746 watts.

What is a Kilowatt or kw.?—1000 watts, kilo merely indicating 1000. It is the most commonly used electrical unit of power and one kilowatt of electrical energy is equivalent to one and one-third mechanical horsepower.

What is a Kilowatt Hour or kw.-hr.?—This is the electrical equivalent of mechanical work, which would be stated in the latter in terms of horsepower hour. It means the consumption of 1000 watts of electrical energy steadily for one hour or any equivalent thereof (such as 5000 watts for 12 minutes) and

is the unit employed by all power companies in selling electric power, their charges being based on a certain rate per kw.-hr. consumed.

What is kva.?—This means Kilovolt amperes or volts$\times$ amperes$\div$1000. This term is used only in alternating current practice and is used to represent the apparent load on a generator. In any inductive apparatus, such as a motor or welder, a counter current is set up within the apparatus itself, which is opposite in direction to and always opposes the main current entering the apparatus. This makes it necessary for the generator to produce not only amperes enough to operate the motor or welder but also enough in addition to overcome this opposing current in either of the latter, although the actual mechanical power required to run the generator is only that to supply watts or electrical energy (volts$\times$amperes) *actually* consumed in the motor or welder. Hence, the kw. demand of a welder represents the actual useful power consumed, for which you pay, while the kva. emand represents the volts$\times$total number of amperes impressed on the welder$\div$1000, to also overcome the induced current set up within, but it is the *kva. demand* that governs the size of wire to be used in connecting up the welder. Kw. divided by kva. of any machine, represents the power factor of that machine, which is usually expressed in per cent.

INDEX

D

F

M

N